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DISEASES AND DEFORMITIES OF THE SPINE AND THORAX

ARTHUR STEINDLER

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DISEASES AND DEFORMITIES
OF THE
SPINE AND THORAX

BY

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PREFACE

As this book on *Diseases and Deformities of the Spine and Thorax* is presented, the writer is conscious of a departure from the usual conception and plan of books serving a similar purpose. In the endeavor to develop the topic coherently and logically, a tendency to dwell broadly upon the basic and theoretic considerations, and upon experimental evidence has come, too much perhaps, into the foreground.

Yet this plan of developing the subject with strong emphasis upon its theoretical and experimental foundation, reprehensible as it might seem to some who are eagerly bent upon practical application, has been adopted intentionally and deliberately, backed by a rather large experience in orthopedic teaching.

Some explanation for the adoption of this policy is due.

It should be the foremost effort of a book of this kind to develop orthopedic judgment, or, as Sir Robert Jones so aptly puts it: orthopedic conscience. Without it no perusal of books will enable the reader, be he general practitioner or specialist, to apply to a given contingency the proper decision.

Medicine, in the writer's opinion, is never light reading. He professes himself as unalterably opposed to the idea of imparting to the busy practitioner his necessary knowledge in form of an easily readable and profusely illustrated compendium, top-heavy with advice and information on all the technical details of treatment.

The reader is entitled to have developed for him a coherent story: one that embraces all the concatenated events leading up to the clinical situations with which it is the purpose of this book to deal. In so doing, one must draw upon all available resources of knowledge, no matter how far back one may have to turn; as long as it is necessary for logical comprehension of the subject; as long as one is, in the light of our present knowledge, reasonably sure of establishing facts and of avoiding fancies; and as long, last but not least, as it can be told in simple and unequivocable terms.

That the development of independent judgment is even more essential in orthopedic questions than in other lines of surgery, becomes obvious to the reader when he realizes the flux of opinions and the ever-changing tide of the therapeutic conceptions, so often embracing the most contradictory interpretations of experiences and facts, in which the history of orthopedic surgery abounds so fully. After he has forced his way through a flood of opposite opinions what is the harassed practitioner to do? Certainly, no justice can be done to the case by adopting a partisan standpoint. All opinions are needed and must be heard and explained to the reader. Therefore, in some of the questions judgment must be deferred, or at least qualified; to mention only one: that on the merits of operative fusion of the spine. After all pertinent factors are duly developed and carefully analyzed, the reader is better able to form his own judgment than he would be if the writer in expressing his own individual views should give undue force to one side of the question. This is the reason why embryologic, anatomic, physical, and mechanical considerations have been brought in so prominently. We considered it necessary in order to bring the reader's judgment to fruition so that he himself may feel in control of the situation.

As much as we depend upon individual facts of pathologic and clinical nature as much do we stand in need of reliable statistics. There is no reason why medical statistics could not be as reliable as are vital statistics. They must, however, be constructed with consideration of all pertinent factors. In this book only those statistics are used which, by weight of figures and reliability of observation, have a claim on force and conviction.

In discussing therapeutic methods dogmatizing has been carefully refrained from. Where it is necessary to dwell upon detail regarding the objective of treatment and its more intricate technic, the underlying mechanical and pathologic factors are emphasized as much as it was thought necessary for a logical development of the rationale of the method. In the description of detail we thought it not necessary to go too far. When the object of the treatment is fully explained, and the salient points of the technic are given, obvious and self-evident details of technic can often be spared the reader who is expected to be conversant with general surgical routine. An illustration often will help much better over difficulties of technical details than a circumstantial description.

Acknowledgment is due and gratefully rendered to Dr. H. J. Prentiss for his help in some of the anatomic questions; to Dr. J. Milgram for his very valuable assistance in compiling records and illustrations; to Drs. L. Miltner and J. LeCoque, L. Lucas, and P. Sherwood for their help in preparing the statistics; to Mrs. B. Ingham for valuable assistance in the dictation and compilation of the text; and to Misses Hickok and Dixon for some of the illustrations; and to the publishers, the C. V. Mosby Company and staff for their painstaking labor and helpful interest in the publication of this book.

ARTHUR STEINDLER.

Iowa City, Iowa.

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INTRODUCTION

No doubt congenital deformities of the spine and thorax are of great interest to the student of embryology and prenatal pathology. But what is, on the whole, the practical significance and importance of such deformities?

Up to comparatively recent times congenital deformities of the spine were considered rarities; they were seldom recognized except in extreme forms, and little practical importance was attached to them. In later years, however, there has come a radical change in our views on the importance of these deformities, thanks to the influx of a great deal of clinical and pathologic information, supported by roentgenologic evidence. Now, congenital deformities are not only much more frequently recognized than they ever were before, but their significance for the organism as a whole is much better understood. We know now that such congenital deformities of the spine have a definite influence upon the functions of the more remote parts of the body, that they are a factor, in pathogenesis, not only of changes situated close to the deformed spine but also of others established at peripheral portions of the body (LeDouble, 1912).[78]

This point is illustrated, for instance, in cases of congenital wry neck, where the underlying deformity is often a congenital anomaly of the cervical spine; or in cases of congenital scoliosis produced upon the basis of congenital anomaly of the spine; the long range of effect of the congenital anomalies of the spine is illustrated by the production of those congenital deformities of the feet, or hands, which will be the subject for discussion in the Chapter on Spina Bifida. For the practical surgeon an appreciation of congenital anomalies as the cause of deformity is indispensable.

With the added material of facts we are now in better position than ever to present a more coherent, though still far from complete, narrative of the causes, the appearances, and the effects of congenital deformities of the spine.

Congenital defects are either developmental or intrinsic; or mechanical or extrinsic; both factors, occurring singly or combined, lead to deformities and functional impairment of the spine of all types and degrees.

From the viewpoint of the phylogenetic tendency we may with LeDouble,[78] divide the deformities into hereditary or reversive ones in which there is evident a propensity of reversal to type (atavistic); and in functional or progressive ones in which a forward trend of phylogenetic development becomes apparent (futuristic type). In general, the earlier the period into which falls the origin of the developmental defect, the greater and more formidable is the subsequently developing anomaly. Some of the most formidable developmental arrests of the spine date back into the blastematous period of embryonal life, but of such formidable maldevelopments we see comparatively little because they are, on the whole, not compatible with life. The spinal anomalies with which we are principally concerned are those of the less extensive type, those whose origin usually falls into the neofetal period (fortieth to fifty-sixth day).

1. The Pathogenesis of Congenital Deformities of the Spine

The critical period of most of the congenital anomalies of the spine is the transition into the osseous state, and the pathogenesis of these deformities is intimately interwoven with the mechanism of ossification.

a. Primary Ossification Centers.—According to Keith the cartilaginous stage commences at the fifth week; soon after, there appear, in each vertebral half, three centers of ossification; namely, one for the neural arch, one for the costal process, and one for each half of the center of the body. This ossification of the spine begins in the so-called neofetal period, that is, from the fortieth to the fifty-sixth day of life, and it does not end until a far-off postnatal period. The fact that ossification reaches into the juvenile and even into adolescent life is of great clinical importance; it explains the appearance of many of the so-called late symptoms otherwise difficult to understand. In the seventh week the nuclei in the bodies of the vertebrae appear, one for each half, and soon fuse together. In the third month the ossification centers of the neural arches have made their appearance in the dorsal region and somewhat later in the lumbar and sacral regions; by the fifth month the ossification of the bodies has proceeded close to the surface, occupying most of the vertebral structure. The arches begin to ossify in the twelfth week of intrauterine life; the costal elements not until after the sixth month and the ossification of the lateral masses of the sacrum is still slower. Fusion of the centers of the bodies of the vertebrae with the arches does not occur until the fourth and fifth year, and in the sacrum not before the fifth and sixth year of life. The basal part of the arches takes part in the ossification of the posterior portions of the bodies.

b. The Secondary Centers of Ossification.—Aside from the three primary centers of ossification, secondary centers develop in the apophyses.

Epiphyseal ossification centers appear at the upper and lower surface of the vertebral bodies from the eleventh to the fourteenth year and they fuse with the bodies between the eighteenth and the twentieth year. Other secondary ossification centers also appear for the costal elements of the cervical and lumbar sections, as well as corresponding nuclei for the ribs. The latter ossify from a center appearing at the vertebral end toward the seventh and eighth embryonal week, ossification progressing slowly forward toward the cartilaginous portions of the rib. Secondary ossification centers also appear at the tips of the spinous and of the transverse processes.

2. Classification of Congenital Anomalies of the Spine

It is to be expected that the intricate conditions under which the ultimate ossification of the spine is arranged give rise to innumerable irregularities and departures from the normal development. According to Dwight[39] variations may occur in different ways: by irregular development of the costal elements, by anomalies in the normal segmentations of the different metameres of the spine, by suppression or intercalation of vertebrae, by defects in ossification, etc.

On similar grounds Putti[100] distinguishes three types of vertebral anomalies:

a. Morphologic variations.
b. Numerical variations.
c. Errors in regional differentiation (suppression).

a. The morphologic variations consist in production of wedge-shaped vertebrae, or independent body halves, or other signs of developmental arrest of the anterior portions of the vertebra. Morphologic variations of the posterior portions of the vertebrae are represented by failure of the separate centers of one arch to fuse, an occurrence which leads to pseudoarticulation between arches and pedicles, as seen occasionally in the lower lumbar section of the spine (Spondylolisthesis).

To the morphologic variations belongs also the formation of half vertebrae, both in the dorsal and the lumbar section (Plate I, 1, 2, 3). In a case described by Zanoli[136] half vertebrae were found at the lumbodorsal intersection representing four half bodies of which the two upper ones belonged to the dorsal section and the two lower ones to the lumbar, a state of so-called hemispondylia cruciata duplex. There were also other aberrations in this case; for

PLATE I

Fig. 1.—Hemivertebra in dorsal spine.

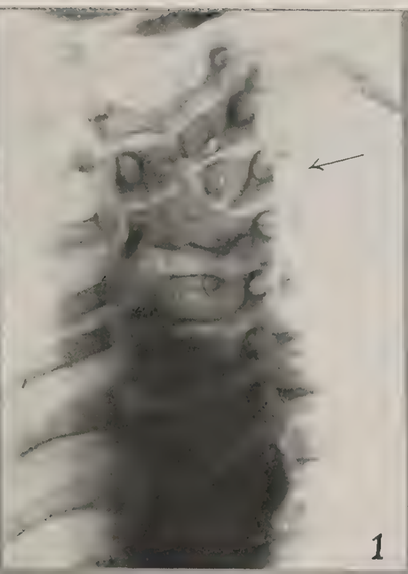
Fig. 2.—Hemivertebra 5th lumbar. (Patient appears in Fig. 3.)

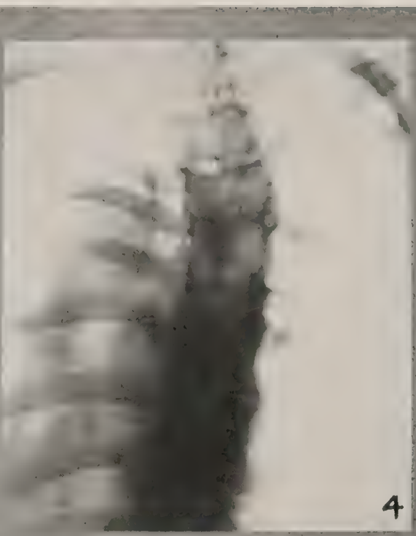
Fig. 3.—Hemivertebra 5th lumbar. Congenital scoliosis, post-Hibbs fusion. Hypertrichosis present.

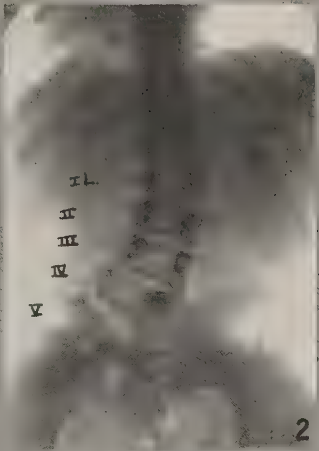
Fig. 4.—Congenital fusion of 3rd to 7th dorsal vertebrae.

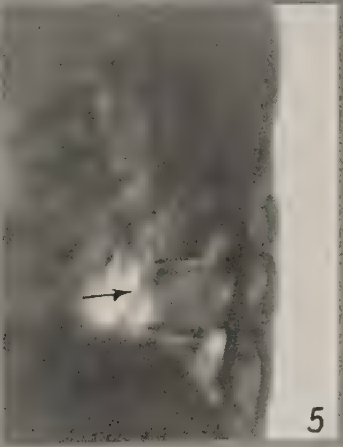
Fig. 5.—Congenital fusion of 11th and 12th dorsal. Congenital shortening of right lower extremity—1 inch.

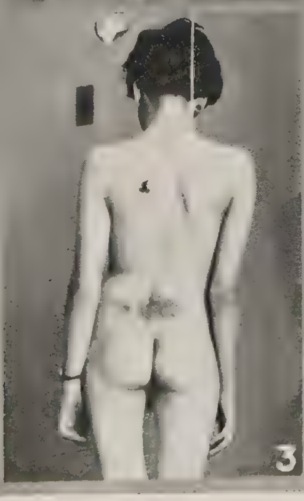
Fig. 6.—Congenital fusion of 3rd, 4th, 5th lumbar and 1st sacral. Lumbar lordosis is effaced in patient.











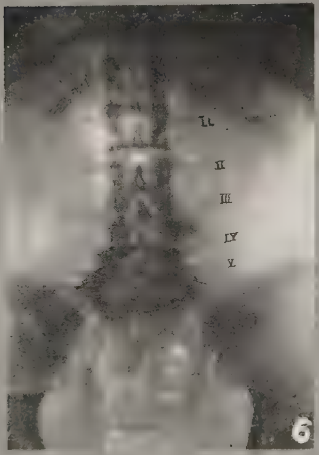


PLATE I

instance, the lateral masses of the third, fourth, and fifth lumbar were fused together, and there was an asymmetrical ascension of the sacrum. The explanation of such anomalies is that the lateral masses of the lumbar vertebrae represent the costiform apophyses of the lumbar vertebrae and that the case was one of retrogressive modification. The lateral masses which are normally suppressed in the lumbar spine developed as they do in the sacrum and had become fused into a solid block. To morphologic aberrations also belong cases of synostosis of vertebrae at different levels (Drehmann);[35] (Plate I, 4, 5, 6) cases in which the dorsal or lumbar spine, or sections of it, represent nondescript fused masses, so that the individual segments can no longer be recognized. To this group also belong the fusions of the cervical spine known as the syndrome of Klippel and Feil,[74, 75] which is the anatomic basis of the congenital short neck. In these instances the spine has become arrested at a very early developmental stage when it still forms an unsegmented cartilaginous rod. To this rod the ribs are joined, radiating fan-shaped from this undifferentiated mass of fused vertebrae. Boehm[18] describes eight cases in which the lower lumbar vertebrae were fused into one piece without differentiation. In milder degrees of fusion one may be at a loss to distinguish between lack of differentiation of the metameric elements and a more simple defect by suppression, or reduction in number of the segments (see group c).

b. Numerical Variations.—The essential feature of these variations is an assimilation of vertebrae either to the cranial or caudal end of the adjacent section of the spine. The most cranially situated instance of such an assimilation is found in the so-called occipitalization (Putti,[100] Lupo,[83, 84] Chiarugi[28]), that is, the fusion of the first cervical to the occiput. Putti,[100] in his careful study on the congenital deformities of the spine, observes that these numerical variations are found principally at the levels of transition of one section of the spine into the other. So, we find them most frequently at the junction between the 7th cervical and the 1st dorsal, between the 12th dorsal and 1st lumbar and between the 5th lumbar and the sacrum.

(1) *Occipitalization (Plate II, 1).*—Taking up first the most cranially situated numerical deformity; namely, the occipitalization of the 1st cervical segment, the question comes up whether one deals with an abnormal spinal segment representing the occiput which is drawn into the cervical spine, or with a transformation of the first segment of the cervical spine into an occipital segment?

All authors who investigated the question are inclined to think that it is the first cervical segment which assumes the characteristics of the occiput (Lupo[83, 84]), and up to now the existence of a so-called occipital vertebra has not been proved. Such anomalies must be classified as assimilation of the atlas to the occiput. Sometimes multiple foramina for the hypoglossus nerve are noted, which may be due to ossifications of fibrous septa, or may be a manifestation of the metameric constitution of the occipital bone (Chiarugi[28]).

This occipitalization is often accompanied by brachycephaly, by malformations and deformities of the mandible, and by true facial scoliosis

(Dwight).[39] Formative errors in the cervical tract are furthermore found in the relative frequent axial assimilation to the 3rd segment, the axis sharing the characteristics of the 3rd cervical vertebrae (Bertolotti,[12] LeDouble[78]).

Bardeen[8, 9] in a study on numerical variations on the cadaver finds that only in 10 per cent the vertebral column showed a tendency to numerical increase. One must distinguish between changes in the modal number of the vertebral metameres, that is, increase or decrease, and changes in which there is increase in the number of segments in one section at the expense of another section, so that the total number of presacral segments remains normal, namely, twenty-four. It is to the latter type that the great majority of numerical variations belong.

(2) *Numerical Variation in the Cervicodorsal Level.*—In caudal direction we observe the formation of cervical ribs, total or partial, at the 7th cervical vertebra; cranial assimilation is represented at this level by the rudimentary development of the 1st rib. In the first instance the 7th cervical segment appears assimilated to the first dorsal, the assimilation moving downward (caudal assimilation, see Cervical Rib, Plate VII, 1-3); in the second instance the 1st dorsal appears assimilated to the 7th cervical, the assimilation moving upward (cranial assimilation, Plate II, 2). In the first instance there is a decrease of the cervical and a corresponding increase of the dorsal segments; in the second instance, the conditions are reversed.

(3) In the *lumbosacral section* we find likewise a caudal assimilation consisting in sacralization of the 5th lumbar in various degrees, ranging from a large, bifid transverse process to complete sacralization of the 5th lumbar segment; (Plate II, 3) the cranial assimilation consists in lumbarization of the 1st sacral vertebra, whereby the number of lumbar vertebrae is increased to six, while that of the sacral segment is decreased to four (Plate II, 4, 5).

(4) *At the Dorsolumbar Section.*

1. In caudal assimilation the 12th dorsal has transverse processes typical for the 1st lumbar vertebra; the costal rudiments of the 12th dorsal approach the character of the costal elements of the 1st lumbar vertebra, and the articular process of the 12th dorsal correspond into that of the 1st lumbar; an inversion, in short, of the 12th dorsal to the 1st lumbar vertebra. Here the assimilation moves toward the caudal end.

2. *The cranial assimilation at the dorsolumbar junction* consists in the so-called dorsalization of the 1st lumbar vertebra which carries a rib (Plate II, 6). Lumbar ribs are not frequent. The first observation of this kind was made by Cruivelhier.[33] Such lumbar ribs may be considered a separate formation when united with the transverse process either by a synchondrosis, or a fibrocartilaginous junction, or a true articulation. LeDouble[78] makes a distinction between lumbar ribs which are merely contiguous with the transverse process and pedicles, and those which articulate with these structures. In the latter type, the rib is differentiated into a head, neck, and body.

Examining 500 radiograms of the lumbar spine Camurati[26] found the frequency of lumbar rib to be 1.22 per cent. This rib may assume a clinical

PLATE II

Fig. 1.—Congenital fusion of atlas and occiput (occipitalization).

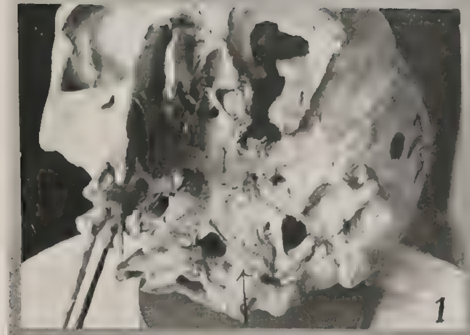
Fig. 2.—Cervicalization of 1st dorsal (cranial assimilation). There are 8 cervical and 11 dorsal vertebrae present. (Actinomycosis of body of 1st cervical.)

Fig. 3.—Sacralization of 5th lumbar (caudal assimilation). (Hemisacralization.)

Fig. 4.—Cranial assimilation of 1st sacral (lumbarization). Articular facet at 1st is in different plane from its neighbor on the opposite side.

Fig. 5.—Cranial assimilation of 1st and 2nd sacral (lumbarization).

Fig. 6.—Dorsalization of 1st lumbar vertebra. Bilateral lumbar ribs (cranial assimilation).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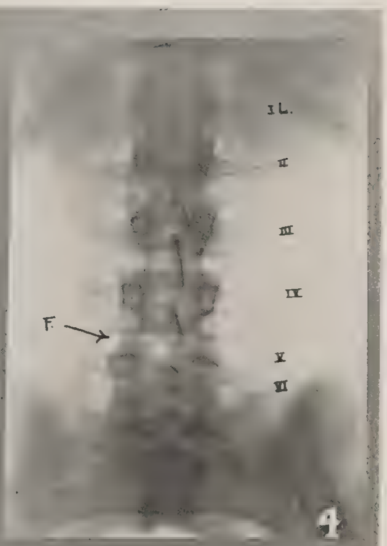
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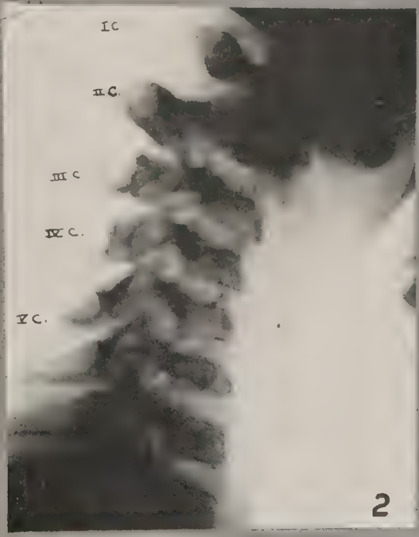
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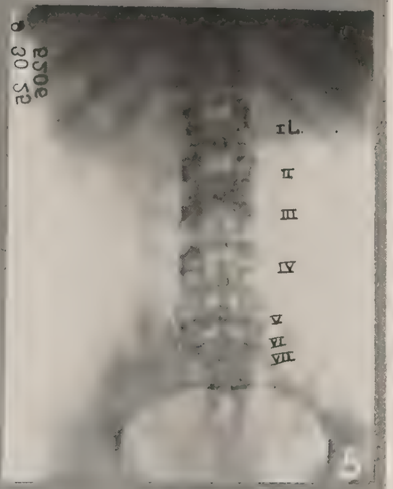
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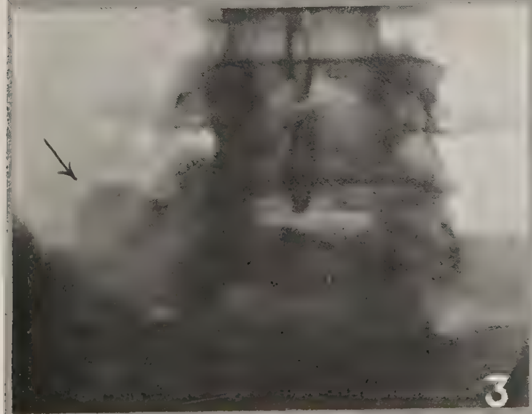
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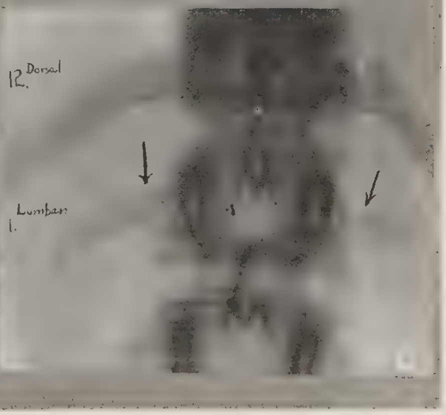

12. Dorsal
1. Lumbar
6

PLATE II

significance, in cases of injury, where a distinction must be made between lumbar rib and a fractured transverse process. This distinction is not always easy. It is of importance to note that the line between the bones is irregular and often oblique, and there is usually a displacement of the fragments in cases of fracture, whereas, in the case of a lumbar rib the shadow is clear, well outlined, and not irregular.

Vasomotor and sensory disturbances are often associated with lumbar ribs. This is explained by Leriche[79] as being due to communicating branches from the lumbar plexus of the sympathetic nerve which become easily involved in strain or traction from a lumbar rib, thereby producing vasomotor and sensory symptoms.

Not infrequently numerical variations are observed in which the shifting segmentation, cranially or caudally, may be followed up through all the sections of the spine (Boehm[18]). The more frequent occurrence is, however, that the error in segmentation occurs at one distinct level only, at the 7th cervical, the 12th dorsal, the 5th lumbar, or the 1st sacral vertebra, proceeding either in caudal or in cranial direction, and increasing, in number of segments, one section at the expense of the other.

(5) *The Frequency of Numerical Variation.*—According to Fischel[42] 22 per cent, according to Bardeen[8] 15.9 per cent of the spines examined show numerical variations. An increase in the presacral vertebrae was found in 12.9 per cent, a decrease in 3.3 per cent. It also seems that the female sex is more inclined toward variation in cranial direction, while the male sex leans more toward the caudal variation. Phylogenetically and ontogenetically the spine undergoes a gradual reduction of the presacral segments, so that a persisting increase of the presacral segments must be considered as an atavistic phenomenon, while a persisting decrease of the presacral segments has a futuristic significance.

According to the relation of the total number of the segments to the varying number of vertebrae in the different sections three types of numerical variation may be distinguished. In the first type there is no change in the modal number, but there are numerical variations in one or the other sections; this is by far the most frequent type. There remain twenty-four presacral vertebrae in all, but one of the sections of the spine becomes enlarged while the other becomes correspondingly restricted in segmental number.

In the second type there are twenty-five presacral vertebrae or more, so that an actual increase exists in the presacral number; this is a reversal to the more atavistic form. So we find in the lower races a higher frequency of six lumbar vertebrae than in the younger races of mankind.

In the third type there are twenty-three presacral vertebrae, that is, an absolute reduction in the number of presacral segments. This is phylogenetically a more advanced type, since it is the developmental tendency of the spine to become shorter and to diminish the number of presacral elements. From the orthopedic point of view these numerical variations of the spine are of greatest interest since they may give rise to a number of pathologic conditions. For instance, cervical ribs, total or partial fusion of the last lumbar to the sacral, sacralization, the formation of lumbar ribs, may be directly or indirectly productive of pathologic syndrome, which owing to their frequency and intensity, often assume a great deal of clinical importance.

c. **Spinal Anomalies by Suppression.**—To this group belong such anomalies as are due to suppression of certain parts of the vertebrae (Plate V, 2). It is usually the posterior part of the vertebra which fails to develop, and to unite with the other half, leaving the vertebral ring patent. Finck,[41] studying a large dissection material, concluded that changes in the vertebrae occurring in form of defects of the spine or the neural arches, or in defective cartilaginous anlages of ossification, are to be considered as the remainder of a more powerful primary aberration. The primary defect does not consist, as it is usually understood, in the simple patency of a certain portion of the sacrum or another portion of the spine, but there is definite arrest in the development of the spine as well as that of the contents of the spinal canal. Sometimes a reconstruction of the defect takes place later in life so that the development of the spine appears merely retarded; at other times, however, definite deficiences persist and then we speak of clefts of the bodies of the spine, due to deficiency or failure of the two separate ossification centers of the bodies to fuse; or we speak of a spina bifida if there exists a failure of fusion of the ossification centers of the pedicles and arches. This occurs most frequently in the lumbosacral region.

The various clinical forms of incomplete closure of the spine which result in a spina bifida vera or manifesta with herniation of the contents of the spinal canal, do not rightly belong within the scope of this treatise. They are objects for study in general surgery. Occasionally, however, a partial reconstruction takes place so that the neural arches proceed to a certain degree of development but finally fail to unite, leaving a more or less extensive defect covered by a fibrous membrane. Further reconstruction may take place subsequently after birth so that the patency may finally disappear and the normal anatomic configuration of the spine may still be attained in later years. Often, however, the development remains arrested at a certain stage of reconstruction, leaving a definite dehiscence or patency between the neural arches without herniation and often without involvement of the contents of the canal or of the integument; we then speak of a spina bifida occulta.

I. SPINA BIFIDA OCCULTA

1. Definition

It was Virchow (1875)[123] who gave the name to this condition, indicating a type of spina bifida entirely concealed under the skin. A hernial sac is absent but there are certain stigmata which arouse suspicion that a developmental defect of this kind exists in the spinal column, usually at or near the lumbosacral junction. These stigmata are: hypertrichosis or the presence of

PLATE III

Fig. 1.—Spina bifida manifesta. (X-ray Fig. 4.)

Fig. 2.—Bilateral clubfoot deformity in association with spina bifida. (See Fig. 5.)

Fig. 3.—Right clawfoot deformity in association with spina bifida. (See Fig. 6.)

Fig. 4.—Spina bifida manifesta. (Patient of Fig. 1.)

Fig. 5.—Failure of union of all sacral arches. (Patient of Fig. 2.)

Fig. 6.—Patency of all sacral and 5th lumbar arches. (Patient of Fig. 3.)

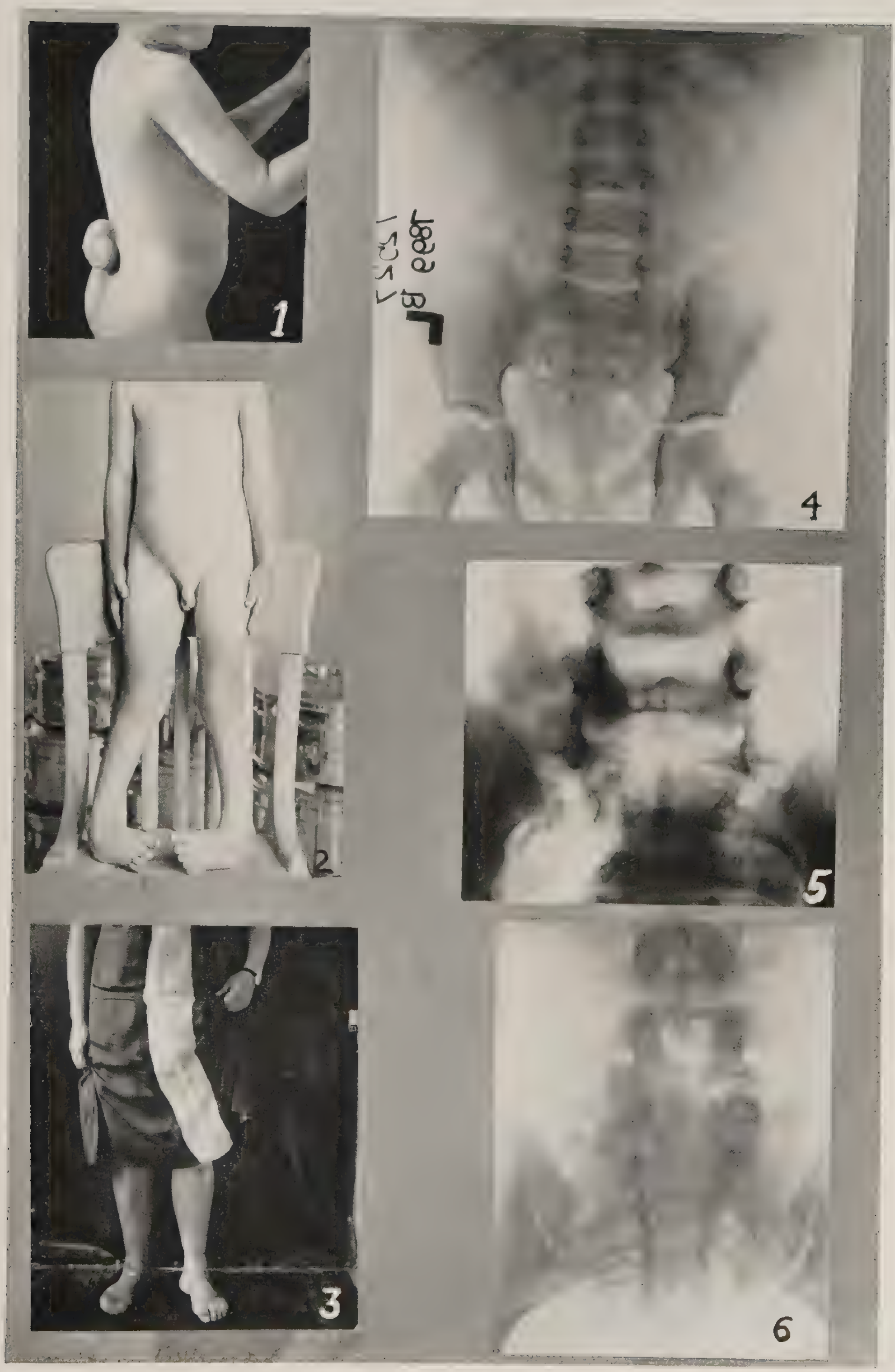


PLATE III

a tuft of hair, a nevus, an area of dilated blood vessels, a hemangioma, a scar, a dimple, or a more or less distinct retraction of the skin.

The point of distinction between spina bifida vera (Plate III, 1, 4) and spina bifida occulta lies in the absence of herniation, and with it the absence of an externally visible tumor. There is, consequently, in spina bifida occulta no accumulation of fluid which is usually a secondary symptom of patency following upon herniation of the contents of the spinal canal (Finck).[41]

2. Pathogenesis

This patency of the neural arch due to failure of occlusion, is the essential feature in spina bifida occulta. It has been stated that later morphologic changes in intrauterine or in natural life may lead to a reconstruction of the defect which may end up in total occlusion, or again, it may stop short at various stages of deficiency.

In the spina bifida vera we distinguish between a caudal or pure form, and a medullary form. The caudal form shows no cyst but the cord passes through the open place in the spinal canal, whereas, in the medullary or cystic form, the cord does not leave the open space being held fast in the lumen of the canal. One may then assume that both the caudal and the medullary form may become occult by the formation of a tough membrane, the so-called membrana reuniens posterior which occludes the open space. Then the distinction between spina bifida caudalis and medullaris is no longer possible.

There is some doubt as to what significance should be attributed to patencies occurring before the eighth year of life; whether they should be considered as permanent developmental arrests, or merely as retardations of the normal ossification which may come to a later occlusion. Theoretically this would imply that a spina bifida occulta should not be diagnosed as a permanent deformity before the eighth year. Most of the observers, however, agree that from the size of the defect conclusions may be drawn much sooner as to its persistence in later life.

3. Pathology

The pathologic basis of the deformity is the defective formation of the neural arches, usually those of the 5th lumbar vertebra (Plate III, 4) and of the sacrum (Plate III, 6), while less frequently those of the upper lumbar, and occasionally those of the cervical or dorsal section are involved. The resulting patency between the rudimentary neural arches is filled out by a tough connective tissue membrane, to which Recklinghausen[103] gave the name "membrana reuniens posterior." This membrane, however, is not entirely intact; it shows a slit through which connective tissue strands, sometimes containing fat and muscle tissue, are seen to run to a cutaneous scar lying over the site of the spina bifida, often within a field of hypertrichosis.

Among his anatomic material Finck[41] found all degrees of posterior rachischisis, from simple defects of the spinous processes to veritable clefts and malformations of the entire arches. Through the slit in the membrana reuniens posterior the connective tissue strands reach the interior of the canal, there to form adhesions with its contents. It seems that the slit in the membrane is wider at first, but later closes down to a narrow line. Sometimes this membrane is found adherent to the skin.

One of the earliest and most classical investigations on the pathology of spina bifida occulta is that of Recklinghausen[103] (1886). Examining a patient with a perforated ulcer at the outer border of the foot who died later following an amputation, he was able to give a very comprehensive description of the essential pathologic signs of spina bifida occulta. He found that the conus medullaris reached as low downward as the 2nd sacral vertebra; he found the spinal canal at the level of the last lumbar and 1st sacral vertebra widened and patent, and the opening filled with fat which seemed to press the cord against the anterior wall of the canal. This fat tumor was observed not only outside the dura but intradurally as well, perforating the soft membranes of the cord. Anteriorly it was easy to separate the dura and recognize it as a distinct membrane, separate from the vertebral bodies, but dorsally it was difficult to dissect it away from the 1st sacral vertebra as it lost itself here in the periosteum. Through the opening in the membrana reuniens connective tissue bundles containing striated muscle fibers were seen to enter into the canal. Over the site of the patency there was a field of hypertrichosis. The lumbodorsal fascia was intact except over the gap where it showed the already described accumulation of fat tissue.

In a later description Bohnstedt[19] (1895) verifies Recklinghausen's observation of the widening of the spinal canal and the cleft of the 1st and sacral segments covered by the membrana reuniens. This author also found the cord to be very long, reaching far into the sacral canal. The medulla ended into an intumescence in the lower portion of the sacral canal, so that the lower roots of the cauda equina had to take an upward course to reach their respective vertebral foramina. The medulla was found to be lengthened to the amount of five segments. Owing to their being embedded into the mass of muscle, fat and connective tissue, the posterior roots could not easily be recognized.

Intraspinal Pathology.—From the clinical point of view the center of interest belongs to the pathologic changes of the nervous structures within the canal. In the case observed by Recklinghausen[103] the conus was situated at the second sacral level, and the medulla was constricted by a myo-fibrolipomatous tumor which crowded it forward and flattened it and led to degeneration of the cord and the posterior roots. The changes seen in cord and cauda equina can be brought into direct relation with the functional disturbances (Beck).[10, 11] Cramer[32] operating on two cases of spina bifida occulta found the nerve fibers entangled in the fat tumor from which they could not be properly isolated. In the connective tissue leading from the fat tumor through the slit in the membrana reuniens there were also found nonmyelinated nerve fibers. At this level the dura is usually missing and one finds the fatty tumor in the canal to extend farther up and down compressing the cord. This observation of cord and cauda being compressed by tough fibrous strands coming from the membrane is corroborated by numerous observers (Jones,[67] Maas,[85] Katzenstein[69]). These strands pressing against the cord hold it back in the lower sacrolumbar canal and, as the spinal column grows the cord becomes more and more stretched and tense. In a case reported (Recklinghausen,[103] and Fischer[44]) the cord was pulled out so far that the caudal nerves had to take a recurrent course upward. It must be assumed, then, that the strands impede the normal upward ascent of the conus medullaris, so that the latter remains at a lower level instead of reaching the second lumbar vertebra where we find it in adult life. The fatty tumor within the canal not only completely envelops cauda and conus, but it also enters into numerous adhesions with the other contents of the spinal canal, extending between the nerve roots and the dura. A combination of congenital syringomyelia and spina bifida occulta has been observed by Klippel and Feil[75] (1921). The former they attribute to hypertension of the cerebrospinal fluid, believing that both syringomyelia and spina bifida are coordinated signs of an underlying developmental aberration.

4. The Peripheral Symptoms in Spina Bifida Occulta

It is chiefly because of a number of apparently uncorrelated peripheral disabilities and deformities which accompany the spinal deformity that the latter becomes of considerable orthopedic interest. When these peripheral manifestations appear at birth or early in life, it is easy to establish the relation between the deformity of the spine and such clinical syndromes. In later years, however, attention has been called to cases in which the spina bifida occulta was associated with deformities and disabilities of peripheral types which appeared after a long period of latency only, and sometimes not until adult age was reached. In those cases it is more difficult to establish a causal connection between spina bifida occulta and such deformities.

So far as the concurrence of local and peripheral signs is concerned the material may be grouped, according to Brickner[23] as follows: (1) cases that have external signs such as nevus, hypertrichosis (Plate I, 3), etc., and also peripheral symptoms; (2) cases with external signs but with no peripheral symptoms; (3) cases which show no external signs but which do have peripheral symptoms; and (4) cases without either external signs or peripheral symptoms. This latter group, naturally, is entirely quiescent and the deficiency in the spinal column is only an incidental finding of the x-ray examination. Nevertheless, such cases may be of potential orthopedic interest because they represent spines that are inherently deficient in structure and offer less resistance to stresses and strains, and consequently often become the background for static and traumatic disorders. The first two groups, embracing cases with external signs and peripheral symptoms, and those without external signs but with peripheral symptoms represent definite congenital malformations often productive of early and sometimes of late clinical sequelae.

These peripheral symptoms again may be classified as follows: (a) sensory or motor paralysis of the lower extremities, with or without trophic changes, and with deformities developing from muscular imbalance; (b) contractures; and (c) symptoms of incontinence of bladder or rectum, or weakness of bladder, enuresis nocturna. (Table I.)

a. Motor and Sensory Disturbances.—

(1) *Progressive paralytic foot deformities in spina bifida occulta.*

While the developmental defects which result in spina bifida occulta occur very early, that is, within the first week of intrauterine life, the resultant peripheral deformity is a very slow and progressive process based upon the overthrow of the normal balance of the foot, the muscles of which are damaged in their nerve supply by the secondary changes in the spinal cord and cauda equina. Three types of foot deformities prevail: the equinus, the varus, and the cavus deformity (Roeren[105]). The cavus or clawfoot deformity is the most frequent and the best known of the late symptoms of spina bifida occulta. The characteristic three types of foot deformities express the tendencies of the natural muscle balance to place the foot under the predominance of the strongest and best developed muscle group. Pathologically this overthrow of balance is due to limited and disseminated areas of paresis.

TABLE I.

RELATION of SPINA BIFIDA OCCULTA to PERIPHERAL DEFORMITIES.

A. CLUB FOOT & SPINA BIFIDA OCCULTA.

Number consecutive cases of club foot deformity. Spines X-rayed	30
SHOWING Sp. B.O.	18
Sacral Cleft	14
Sacro Lumbar	3
Dorso-Lumbar	1
NOT SHOWING Sp. B.O.	12
SHOWING OTHER ANOMALIES + CONGENITAL DISLOCATION of HIPS SYNDACTYLY & ETC.	5

B. SPINA BIFIDA OCCULTA & PERIPH. DEFORM.

Number cases Sp. B.O., 38

Sacral	25	38	Club Foot Def.	19
Dorsal, Lumbar and Sacral	3		Claw Foot Def.	4
Lumbar & Sacral	7		Scoliosis	6
Dorsal & Cervical	1		Incontinence	2
Dorsal	1		General Def.	
			All Four Extrem.	2
			Other Foot Def.	5
			No Periph. Def.	10

For the distribution of these paretic centers the topography of the nerve centers within the anterior portion of the spinal cord is responsible. It is believed that the cell columns representing muscle function for the plantar position of the foot and for the maintenance of the plantar arch are situated farther caudally than those columns which serve the extensors of the toes and the tibialis anticus. On these grounds an attempt is made to furnish a topographical explanation of the typical foot deformities encountered in spina bifida occulta.

i. The Clawfoot Deformity (Plate III, 3, 6).

Bibergeil[13, 14] was the first to call attention to the relation between spina bifida occulta and this type of foot deformity. In his examination of seventeen cases of clawfoot he found x-ray evidence of spina bifida occulta in nine. The majority of his cases showed a cleft of the 5th lumbar vertebra. He expressed the opinion that the progressive clawfoot does not belong to the congenital deformities proper but develops upon the basis of a disturbance of the vertebral skeleton and of the cord. The deformity progresses slowly and insidiously without objective symptoms and is often only observed when it already has produced a definite disturbance in the gait. Even though the chain of events leading from the deformed spine to the foot deformity is not definitely established, the conclusion is justified that the clawfoot deformity develops as a result of the spinal malformation. It is assumed that the difference in growth, especially the inhibition of the ascent of the medulla, is primarily responsible. The pathologic adhesions arising from the membrana reuniens posterior and involving the contents of the spinal canal may be considered in the light of mechanical obstacles to the upward move of the spinal cord. It is possible that the fatty tumors within the spinal canal have a similar mechanical function in impeding the ascent of the cord, the conus medullaris, and the cauda, exerting a pull or traction upon these structures which results in functional impairment.

ii. The Clubfoot Deformity in Spina Bifida Occulta (Plate III, 2, 5).

It was Courtillier and Vulpius[126a] who first expressed the suspicion that central lesions might be responsible for this peripheral deformity; since then extensive investigations have been made on clubfoot as a symptom of spina bifida occulta (Beck[10, 11]), which established the etiologic connection of the two conditions.

Clauss, who examined the lumbar spine and the sacrum in a number of newborn with clubfeet, finds an open sacral canal and patency of the lumbar spine in a large number of the cases. This substantiates the opinion that many more clubfeet must be classified under this etiologic group than is generally supposed, and that, next to the theory of the primary intrauterine pressure the one ascribing the cause of clubfoot to deformities affecting the formation of the spinal column and the central nervous system is assuming greater importance (Hahn[55]). In accordance with Duchenne's explanation, here the disturbance of the muscular equilibrium which leads to the foot deformity is to be ascribed to the compression of the cauda equina. An instance is reported by Jones,[67] where a twenty-two-year-old patient showing signs of paralysis in the lower extremities since the seventeenth year, had a double paralytic clubfoot as well as a mal perforant of the foot.

iii. Flaccid Paralysis.

Aside from the definite foot deformities one also encounters in spina bifida occulta more generalized paralytic disturbances which often appear later in life (Bufalini[25]). Sever[113] cites a number of cases of flaccid paralysis in spina bifida occulta. This type of paralysis is so common in spina bifida vera that its occasional appearance in the occult form is not surprising; it obviously denotes a higher degree of spinal cord lesion (Plate V, 1, see note).

(2) *Sensory Symptoms.*—We encounter hyperesthesias, anesthesias, often of the saddle-back type, in cases of spina bifida occulta similarly as seen in true spina bifida. Some observers report hemianesthesias with sensory as well as motor disturbances (Voelcker,[124] Leri, Engellhard), the sensory symptoms sometimes simulating syringomyelia.

Trophic disturbances are seen in cases of spina bifida occulta of either the cervicodorsal or lumbosacral section. Of all trophic and vasomotor disorders the perforating ulcer, or mal perforant is the most frequent. It may lead to deep necrosis and even to osteomyelitis of the bone and severe phlegmonous condition. In a case reported by Brunner[24] the perforating ulcer led to amputation of the foot. Subsequent microscopic examination revealed hyperplastic granulation tissue and hypertrophic nerve elements were found, presenting the appearance of a hyperplastic neuritis with ample new formation of embryonal nerve fibers. A combination of spina bifida occulta, hypertrichosis, syndactylia, and trophic ulcer at the sole of the foot is described by Fischer[44] (1882).

Brickner[23] relates a number of instances of extensive ulceration at the sole of the foot and toes. He especially noted that the operative wound after amputation healed very slowly, and had very little ability to resist infection. In this connection we might cite a case of our own experience. A girl of nineteen years afflicted with congenital scoliosis and hammer toe deformities, and showing a characteristic tuft of hair at the lumbosacral region, proved, in the x-ray picture, to be afflicted with a spina bifida occulta of enormous extent, reaching from the middle of the sacrum upward into the dorsal spine. A slight infection occurring during operation for retracted toes led to extensive phlegmonous infection of the deep structures of the foot and finally to osteomyelitis and severe septicemia, the patient barely escaping amputation. Lack of inflammatory reaction of the tissues was especially noticeable, presumably due to trophic or neurotrophic changes.

Sensory disturbances are also frequently noted along the distribution of the sciatic nerve, back of the thigh, and at the posterior aspect of the calf, covering the field of distribution of the 1st, 2nd, and 3rd sacral, and the 5th lumbar roots. In other cases where the lower sacral roots are involved a typical saddle back anesthesia may be found.

b. Contractures in Spina Bifida Occulta.—

Of particular interest are the reports on spastic and clonic contractures of the lower extremities seen in connection with spina bifida occulta. Instances are reported of spasmodic contractures of the knees which indicated tenotomies of the hamstring muscles and posterior capsulotomy (Ascher,[6] Nove-Josserand, Allenbach[4]). In other cases permanent flexion contractures occurred successively in the lower extremities and were associated with sensory disturbances and with weakness of the bladder. It was found at operation in some of these cases that a fibroadipose tumor existed which, when carefully dissected, proved to be united to the membrana reuniens by fibrous adhesions. In the case of Allenbach[4] these contractures gradually disappeared after operation.

c. Incontinence of the Bladder.—That there is some connection between spina bifida occulta and bladder incontinence appears from the fact that while in normal individuals only 12 per cent show a lumbosacral cleft, in cases of incontinence the cleft is seen in 60 per cent and more. Incontinence may be produced by a variety of causes, but an occult spinal cleft must always be looked for, especially since this type of incontinence is amenable to relief by operation (See Treatment). (Plate IV, 3, 6.)

d. Unusual Deformities Accompanying Spina Bifida Occulta.—

Four cases of congenital dislocation of the knees were observed by the author (Plate IV, 1, 4).

Congenital Dislocation of the Hip (Plate IV, 2, 5).

Eighteen cases of congenital dislocation of the hip are mentioned by Pieri associated with spina bifida occulta. Beck examining thirty cases of congenital dislocation of the hip found spina bifida occulta in six cases only, and concluded that the defect of the spine is of no particular etiologic importance.

In a case of our own observation a nonunion of the fracture of the neck of the femur occurred in the presence of a spina bifida occulta (Plate V, 1). Congenital contractures (Arthrogryphosis) also are frequently associated with this defect. Several instances of this kind have been observed by the writer (Plate V, 4, 5).

5. The Problem of Latency of Peripheral Symptoms

The lateness in the development of paralytic clubfoot deformity and of other deformities seen in spina bifida occulta has always aroused a great deal of interest. It has been pointed out that the manifestations of the peripheral symptoms, especially the clawfoot and clubfoot formation, falls into the periods of intense growth (Katzenstein[69]). Many observers believe that the initial cause of deformity is the fact that the spinal cord is inhibited by adhesive strands from ascending upward, therefore, at the time when the discrepancy of growth between spinal column and spinal cord is especially marked, the greatest amount of stretching and pulling of the latter structure results. It is, indeed, common experience that these deformities occur most frequently in the two periods of rapid growth, namely, in early infancy and at prepuberty age. On the other hand, it is obvious that this mechanical explanation of the gradual progress of clinical symptoms does not satisfy all cases. Furthermore, this period of apparent latency of clinical symptoms does not necessarily mean the total absence of any pathologic changes.

Still more difficult to explain than the retardation and latency of symptoms, is the progressiveness at adolescence and even adult age. Progression of symptoms is characterized by definite phases of accentuation during the two periods of rapid growth. Most interesting of all is the late occurrence of trophic signs. A case is mentioned by Ascher[6] which, aside from a slight sphincter spasm showed no symptoms referable to spina bifida occula, but developed trophic ulcers after operation for appendicitis. It might well be that in such cases the state of latency was broken by conditions affecting the general health of the patient.

6. The Clinical Significance of Sacrolumbar Cleft

The mere presence of a sacrolumbar cleft does not mean that it has pathologic significance. To assess the clinical value of a spinal defect one must compare its frequency with that of coexisting peripheral symptoms. Compared with the frequent findings of clefts in younger children, cases of spina bifida occulta appear relatively rare in adolescent years, at fifteen or sixteen. Finck,[41] remarking upon the fact, believes that with the beginning of puberty, that is, the eleventh or twelfth year, there is a powerful increase of ossification leading to closure of many clefts. It is substantiated by x-ray pictures taken in adolescents in whom clefts had been found closed which were known to have been present in former years. This is somewhat in keeping with the statements of Spalteholz[114] and other anatomists that the two ossification centers of the arches which appear in the upper sacral vertebrae between the fifth and sixth months, often do not fuse until the seventh to fifteenth year, although as a rule this ossification takes place much sooner.

X-ray Findings.—Finck's[41] series of x-ray pictures established the fact that the percentage of individuals having a lumbosacral cleft is very large in comparison with those showing clinical symptoms referable to it. The total percentage of lumbosacral clefts is estimated by Gressner[51] as 10 per cent and by Beck[11] as 3.5 per cent. There is usually a median cleft of the 5th lumbar as well as of the 1st sacral neural arch and sometimes this cleft extends over several of the sacral segments. More often than not the cleft is not strictly in the median line but is deflected to one side or the other. In other cases one sees an abnormal enlargement of the hiatus sacralis, although the laminae of the 5th lumbar still meet in the middle.

PLATE IV

Fig. 1.—Spina bifida occulta in association with congenital dislocation of knees and ankles. (See Fig. 4.)

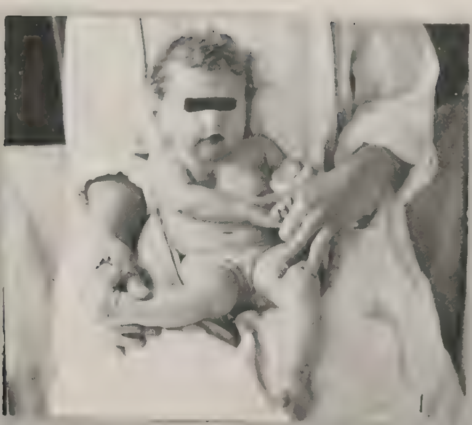
Fig. 2.—Spina bifida occulta in association with congenital dislocation of hips and clubfeet. (For x-rays see Fig. 5.)

Fig. 3.—Spina bifida occulta. Patency of pelvic ring. Extrophy of bladder.

Fig. 4.—Spina bifida occulta and congenital dislocation of knees. (Patient of Fig. 1.)

Fig. 5.—Spina bifida occulta in association with congenital dislocation of hips, bilateral. (Patient of Fig. 2.)

Fig. 6.—Extrophy of bladder; spina bifida. (See Fig. 3.)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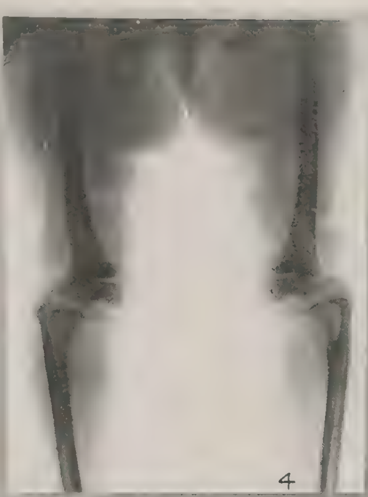
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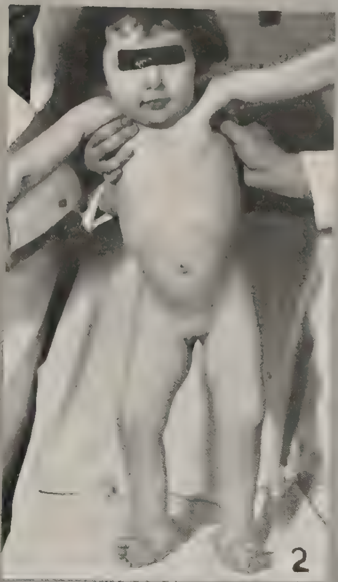
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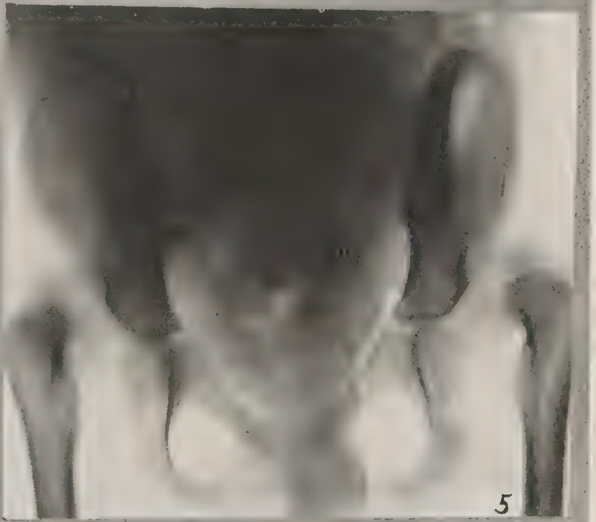
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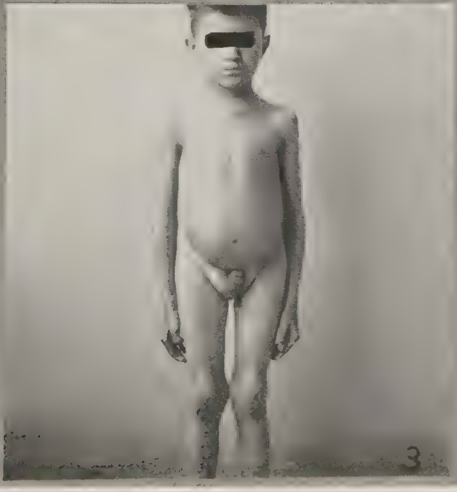
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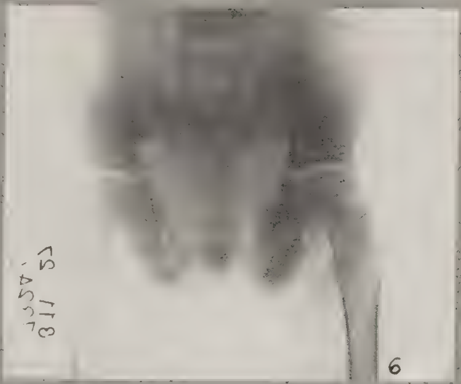
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PLATE IV

PLATE V

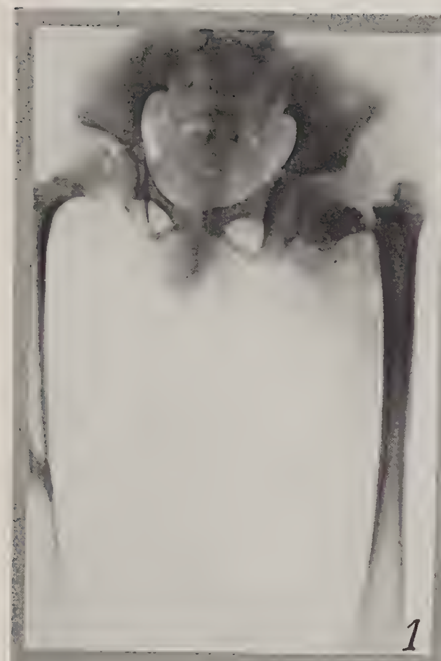
Fig. 1.—Spina bifida occulta. Nonunion of painless fracture of neck of femur two months after accident. Flaccid paralysis and marked sensory loss present in both lower extremities since birth.

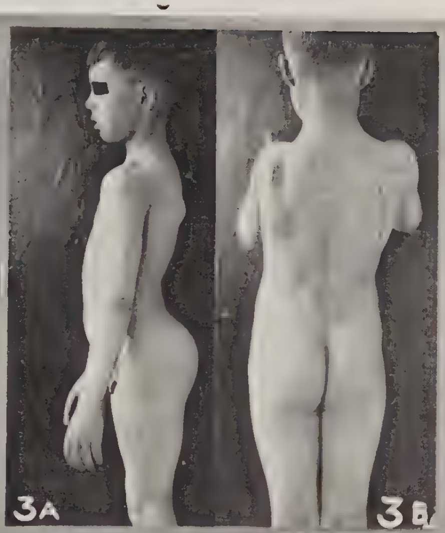
Fig. 2.—Infant aged nine months. Combination of congenital deformities of spine, numerical, morphologic and by suppression. Total absence of sacrum. Hemivertebrae. Rib fusions. Congenital dislocation of hips. Megacolon.

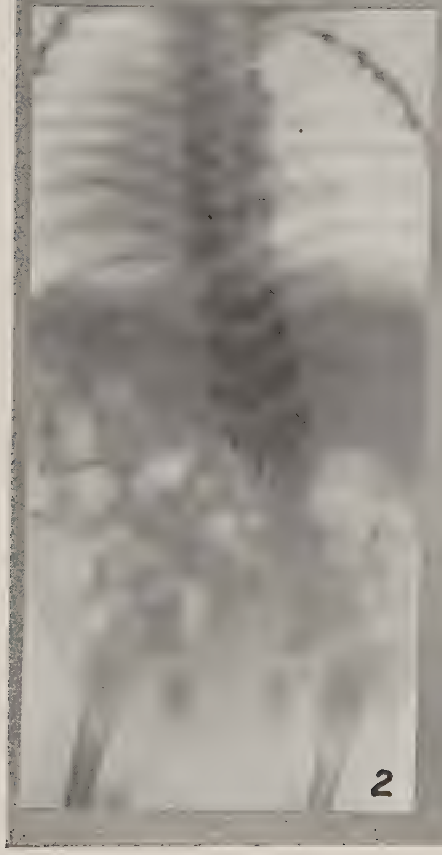
Fig. 3.—Congenital absence of scapular muscles.

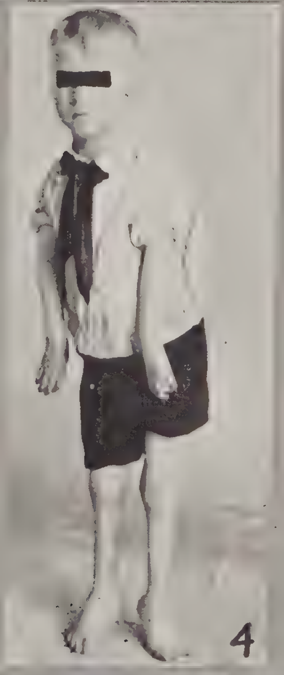
Fig. 4.—Spina bifida occulta in association with arthrogryphosis (congenital contractures).

Fig. 5.—Spina bifida occulta in association with arthrogryphosis.









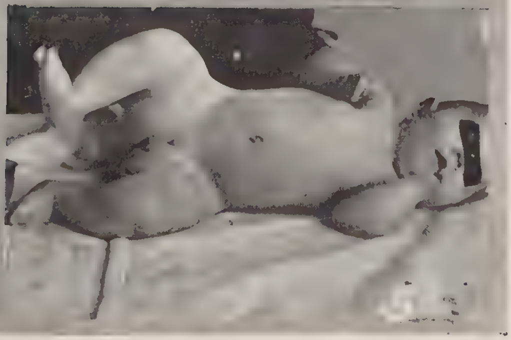


PLATE V

Asymmetry of the 5th lumbar vertebra is a frequent phenomenon and occasionally spina bifida occulta is associated with suppression of one-half of the 5th lumbar vertebra; this obliquity of the upper surface of the vertebra leads to a deflection of the lumbar curve with a resulting scoliosis.

Various other developmental anomalies associated with spina bifida occulta are revealed by x-ray examination. For instance, the lumbarization of the 12th dorsal was found associated with the cleft of the body of the 7th dorsal, clefts of the body of the lower dorsal were seen associated with maldevelopment of the arches. Perussia[98] cites a case of synostosis of the 12th dorsal with the 1st lumbar; in other instances a double rachischisis both in the dorsal and lumbosacral region has been observed. In associated low dorsal clefts it may become doubtful whether the sacrolumbar or the dorsal spina bifida occulta is responsible for the peripheral deformity (Zanoli[46]).

Clefts are seen occasionally in the bodies of the vertebrae alone (Anterior spina bifida occulta or rachischisis). These anomalies usually occupy a higher level preferably the middle and upper dorsal spine.

7. The Treatment of Spina Bifida Occulta

The treatment of the secondary peripheral deformities developing from the malformation of the spine does not belong under this heading. These conditions must be dealt with according to generally accepted orthopedic principles applying to these types of deformity.

a. Indications.—The treatment of the spina bifida occulta itself is obviously a surgical one. Indication for operative treatment exists in selected cases, in adults especially, when progressive symptoms are present, and above all, in cases showing trophic and circulatory disturbances in the lower extremities; also in cases of incontinence of the bladder and of the rectum. Spastic symptoms, mal perforant, advanced clubfoot deformities may also give occasional indications for operation. One may hope for improvement after operation in all cases in which there exists a suspicion of strand adhesions, or a tumor compressing the cord, and the later the disturbances develop, and the sooner, on the other hand, operative treatment is instituted after the symptoms have appeared, the better in general is the outlook. Sever[113] considers the operation indicated in all severe peripheral disturbances, others (Cramer[32]) particularly select the foot deformities which are still progressive as suitable for the operation. Some of the most satisfactory results are obtained in cases with trophic symptoms. Brickner[23] considers operation indicated in infants and children with spina bifida occulta even though there are at the time no remote symptoms, the object of the operation being the prevention of later developing grave symptoms by removing the obstacle to the free ascent of the spinal cord. The indication, naturally, centers around the point whether there is a mechanical obstacle binding the cord down, or whether one has to deal with a congenital defect of the cord itself. The question of meningeal adhesions may sometimes be settled in an x-ray examination by injection of lipiodol into the spinal canal.

b. Technic of the Operation.—The operation consists in careful dissection of the lumbosacral region and the removal of the lipomatous tumor if such is present. If the membrane is then incised there will be found within the canal a white fatty tumor mass lying upon the anterior ridge of the cauda equina. This tumor is also carefully dissected and removed, and if there are any nerves adherent to the inner surface of the sac they are carefully freed and allowed to fall into the cavity.

c. Statistics on Operative Results.—Statistical data on the operative treatment of spina bifida occulta are scarce. In the case reported by Jones[67] (1891) a broad fibrous band was removed and after its removal there was seen a groove in the cauda equina caused by the pressure of this band; following the operation the paralytic symptoms disappeared. This is the first successful operation for spina bifida occulta on record (Bohnstedt[19]). Maas[85] (1897) removed a fat tumor sitting upon the fibromuscular membrane which occluded the defect and pressed upon the cord. In this case there were signs of spasticity in the legs and of the gait, which improved upon operation. Katzenstein[69] reported the third successful case—a resection of the fibrous membrane and of a bone ridge at the 1st sacral level was carried out upon a patient who suffered with perforating ulcer. Following the operation there was improvement of the ulceration of the bladder. In Brickner's[23] series good end-results are reported mostly in cases showing vasomotor and trophic symptoms. It need hardly be emphasized that in cases in which there is a definite deficiency of the medulla or a malformation of the cord no results can be expected from the operation; but, with the exclusion of such cases, one must expect that in suitable cases the surgical intervention alone is able to restore the impaired function of the cord.

II. SPONDYLOLISTHESIS

1. Definition

As the name implies (spondylos: vertebra, olisthemi: glide), the condition is one in which the fifth lumbar vertebra has become displaced forward upon the upper and anterior surface of the sacrum. To this end it is essential that the body of the 5th lumbar vertebra be released of its normal attachment to the upper surface of the sacrum so that it may project itself forward in a more anterior plane. The body then forms a projection over the sacrum, crowding the latter backward. While this displacement most commonly occurs between the 5th lumbar and the sacrum similar displacements are seen occasionally between the 4th and 5th lumbar vertebrae.

The immediate factor which produces the forward gliding of the vertebra is the superincumbent weight transmitted through the body to the lumbosacral junction. It is obvious, however, that under normal conditions such a displacement could never come to pass. There must be special anatomic reasons in the construction of the 5th lumbar which allow of such a displacement, and only by virtue of these anatomic anomalies of the 5th lumbar vertebra can its relation to the sacrum be affected in such a manner that displacement may actually take place. As it is usually understood, then, spondylolisthesis is essentially a congenital anomaly of the spine. This does not preclude that the actual manifestation of symptoms may be precipitated by superinduced trauma. If we exclude from momentary consideration the enormously rare occurrences of a complete traumatic separation of the 5th lumbar from the sacrum, there are still ample instances in which the classical syndrome of spondylolisthesis makes its appearance after a more or less violent injury.

2. Historical

When the deformity was first recognized and described by Killian in 1854 only four known anatomic specimens were at hand. Neugebauer,[95, 96] who, following the initiative of Lambl[77] of Moscow, first devoted serious study to this anomaly, was able to collect in 1884 forty-five cases in the literature, a number which swelled to 101 in his second communication[96] eight years later. These early studies were deepened and amplified by numerous contributions in recent years so that at present we are in possession of fairly accurate information as to the nature of this condition.

3. Pathogenesis

What is this congenital anomaly which makes a displacement of the 5th lumbar vertebra possible?

From the early descriptions it would appear that the part which connects the vertebral body with the arch is either thinned out, or separated entirely, either unilaterally or bilaterally. All of the recent observers (Kleinberg,[72] Chiari,[27] Turner, Tscherkin,[122] and Lovett[82]) are agreed that it is a condition of separation rather than of a thinning out and elongation of the neural arch, as was the older conception of the gynecologists.

Originally, the causes for this separation of the anterior and posterior portions of the lumbar vertebrae were classified by Neugebauer[96] as follows: (1) there is a separation, on one or both sides, between body and lamina due either to defective development or to fracture; (2) or a primary disease of the sacral vertebral articulations, or a vertebral deformity due to superimposed weight.

We know now that the anatomic anomalies which lead to the forward sliding of the 5th lumbar is a true separation of the neural arch from the rest of the body.

To the classical studies of T. A. Willis[133] we owe not only a minute description of the deformity but also a very satisfactory explanation as to its pathogenesis.

We recall from the introductory chapter that the vertebral body ossifies from one center of ossification, or occasionally from a pair of centers which become confluent at an early date. The ossification of the neural arches depends upon two lateral centers, one for each side. Occasionally these lateral centers split into an anterior half which produces the pedicles and the upper articular process, and a posterior half which produces the neural arch and the lower articular process. Willis found that the split ossification centers of one neural arch may fail to fuse, so that a pseudarthrosis or false joint is formed between the pedicle and the neural arches (Plate VI, 1). It may also occur that the fusion between the body and the pedicle fails to take place in which case an articulation appears between pedicle and vertebral body. This condition is called spondylolysis, meaning a separation of the anterior and posterior vertebral halves, and it is to be considered as the anatomic basis of the typical spondylolisthesis (Chiari,[27] Braus and Kolisko[22]). In this manner the bony anchorage between the 5th lumbar body and its neural arch is lost and with it also the alignment between the body and the adjoining surface of the sacrum. The stability of the lumbosacral junction is now depending entirely upon ligamentous structures, notably the ilio-lumbar, the sacroiliac, and the intra- and supraspinous ligaments. It is quite plain that such an arrangement does not offer the same resistance to static and dynamic stresses which obtain under normal conditions. The slipping of the vertebrae cannot occur as long as the inferior articular process of the last lumbar vertebra remains in the usual relation to its body and to the superior articular process of the sacrum.

As the body of the 5th lumbar slides forward over the sacrum the latter assumes a more vertical position than normal; in early stages, therefore, the lumbar spine appears flat. As the sliding of the 5th lumbar spinous process over the sacrum proceeds there appears between it and the top of the sacrum a recess or step, signifying the disalignment between the 5th lumbar body and the sacrum.

a. Trauma and Spondylolisthesis.—The relation of trauma to spondylolisthesis is that of a secondary and superinducing factor.

In two cases in which the spondylolisthesis appeared after trauma Kleinberg[73] encountered all the cardinal signs usually associated with this deformity, namely, the prominence of the sacrum, the hollow at the upper sacral end, the pain in the back and lower extremities, the tenderness in the lumbosacral region. Here symptoms were brought about after apparently complete quiescence and latency, in one case by a blow against the back, and in the other by a fall of a heavy weight upon the shoulders. Such cases and others mentioned in the literature might imply that the trauma was possibly responsible for the condition. On closer examination of the patient, however, one will find that the back was never entirely normal, that occasional fleeting symptoms of spinal insufficiency existed, so that the trauma could be accorded no more than the rôle of a superinducing secondary agency.

4. Pathology

The separation of the 5th lumbar neural arch from its body was found by Willis[133, 134] in 4.8 per cent among a series of over eight hundred spinal columns. He was able to demonstrate fibrocartilaginous areas in the arch as a

PLATE VI

Fig. 1.—(After Willis.) Spondylolysis. Pseudarthrosis between laminae and pedicles.

Fig. 2.—Lateral view of spondylolisthesis. (Patient of Fig. 4B.)

Fig. 3.—Horizontality of sacrum. Pseudospondylolisthesis. Symptomless. (See Plate VIII, Fig. 1B.)

Fig. 4.—(C) Spondylolisthesis. Note "step off" and shortening of trunk.
(B) Spondylolisthesis. (See x-rays Figs. 2, 5.) Peripheral symptoms. Contracture of right knee. Atrophy of left lower extremity.

Fig. 5.—Anteroposterior view of spondylolisthesis. (Patient of Fig. 4B.) Note upward tilt of arch of 5th lumbar and 4 lumbar vertebrae in this view.

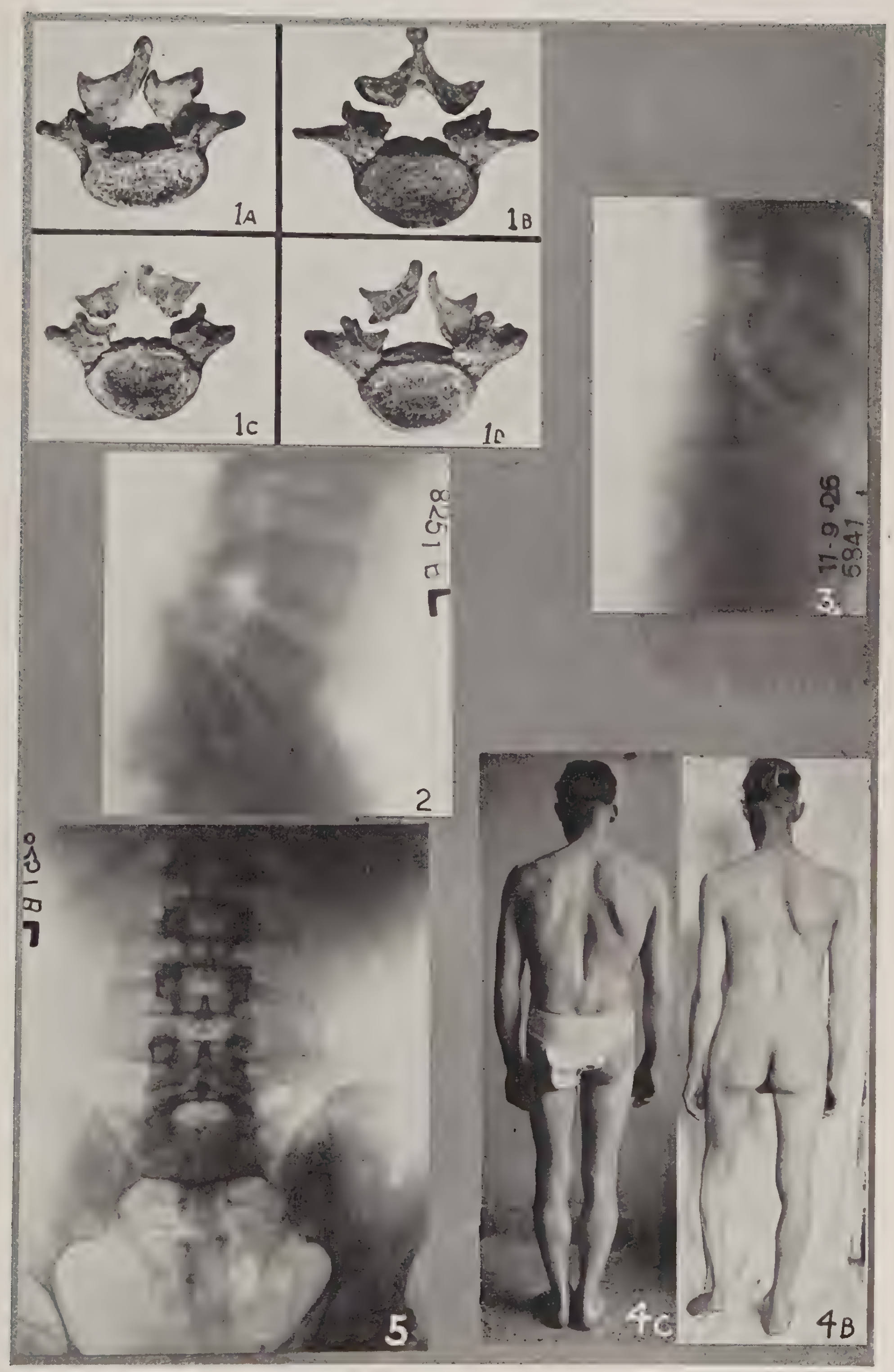


PLATE VI

cause of the anterior displacement of the vertebral body. The malformation consists essentially in an incomplete neural arch with bilateral defect of the lamina; then in an asymmetry of the articular facets and an increase of their obliquity (Wilson[135]). A complete displacement of the lumbosacral facets does not take place, but there is rather a striking abnormal mobility in the anteroposterior plane in the neural arches, as can be demonstrated at operation. In eight cases cited by Wilson[135] there was a separation of the articular lumbar and sacral facets. In one case there was found a fracture of the inferior articular process of the 5th lumbar vertebra. The spondylolisthetic vertebra, therefore, shows, according to most observers, a failure of fusion of the entire neural arch with the pedicle so that the vertebra consists of two parts, a ventral one including the body and pedicle and the upper articular process, and a dorsal one including the arch and the lower articular process (Putti[100]). These two portions of the spondylolytic vertebra are usually in ligamentous or pseudarthrotic connection. From this state of spondylolysis the true spondylolisthesis ultimately develops. Putti finds the separation slightly uneven and showing small osteophytic growth at their margin. The lower articular process belonging to the dorsal half of the vertebra points forward and downward. The vertebral foramen appears triangular and somewhat narrow. Such morphologic anomalies as described by Putti and others are very eloquent corollaries to the hypothesis of the two separate ossification centers of the neural arches which had failed to unite. Keeping in mind these anatomic changes the effect of trauma can now be better evaluated. That it is only a superinducing element in the production of deformity has been mentioned; but it also seems to be a necessary contributory factor. All cases of Wilson[135] were due to severe trauma, and one to prolonged physiologic strain. The application of force in his cases was exactly the same as in the purely traumatic cases reported by Kleinberg.[73] It is believed that forcible extension of the spine is the favored position which facilitates the displacement of the 5th lumbar vertebra.

X-ray Evidence.—Spondylolisthesis can be recognized unequivocably by demonstrating in the x-ray picture the forward displacement of the 5th lumbar upon the sacrum. (Plate VI, 2, 5). It is essential to show that the 5th lumbar has actually altered its relation to the upper surface of the sacrum. In the anteroposterior view the tilt of the 5th lumbar against the sacrum is manifested by a foreshortening of its contours. The upward tilt of the neural arches is recognized by the abnormal largeness of the vertebral foramen; yet the anteroposterior view gives no definite information as to whether the 5th lumbar has actually left its contact with the sacrum or is still in full alignment with it. Kleinberg describing traumatic spondylolisthesis reports two cases which, according to the x-ray findings, are undoubtedly of true spondylolytic nature, that is, they show a distinct evidence of nonunion between arches and body. The salient point of the anatomic, as well as the x-ray situation is that a displacement of the 5th lumbar arch does not occur, but that the body merely moves forward while the articulating neural arch remains behind, which, owing to the existing spondylolysis or pseudo-articulation between body and arch, it is able to do. As the spinous process of the 5th lumbar tilts upward, it appears in the x-ray picture in close contact with its fellow above so that the vertebral foramen comes into full view. But the mere tilting of the 5th lumbar vertebral body upon the sacrum, as revealed in the anteroposterior view, is not a pathognomonic feature of spondylolisthesis. The lateral view is of much greater importance and is more binding for the diagnosis. Here the last lumbar body can be seen to overlap, wholly or in part, the anterior edge of the sacrum, and to project more or less distinctly forward.

5. Incidence

Considering the frequency with which other developmental anomalies, such as spina bifida occulta, asymmetry, sacralization, etc., are found in the 5th lumbar vertebra it is not unlikely that the developmental defect which underlies spondylolisthesis is also more frequent than is generally assumed, and that, while the fully developed spondylolisthesis gives characteristic x-ray evidence, minor defects of the neural arches, for instance, simple spondylolysis, may escape detection. It seems that the female sex preponderates in true spondylolisthesis, although cases in the other sex are by no means uncommon. Our own statistics show an approximately even distribution of the condition among the two sexes.

6. The Clinical Symptoms

a. History and Local Signs.—The patient presents himself complaining of pain localized in the lumbosacral angle or the coccyx, frequently also in the leg. He notes increasing stiffness of the lower portion of the back. This discomfort is decidedly aggravated by strain or exercise. Trauma is usually given as the eliciting cause of the trouble. On closer inquiry, however, it appears that the back never has been strong, or even sufficient for the exigencies of daily routine. On further questioning one may learn that the patient has always had an abnormal looking back, a peculiar shortness of the trunk, or a peculiarity of the gait.

On examining the patient first for signs of anomaly in configuration of the back one notices the shortening of the lumbar segment, the hollowness at the lumbosacral angle and a lumbar lordosis of moderate degree. If there are signs of acute strain one also finds a bilateral muscle spasm of the long muscles of the back and with it a limitation of motion, particularly in anteroposterior direction. There may also be a marked spasm of the hamstring muscles brought out by the straight leg raising test. The limitation of motion of the spine is constant in either sitting, standing, or recumbent position, due to the persistent spasm of the erector spinae muscles. There is definite localized tenderness of the sacrolumbar region.

The shortness of the trunk is largely due to the downward descent of the 5th lumbar body upon the sacrum, the characteristic feature in spondylolisthesis; but there is also a decided decrease of the pelvic inclination; the sacrum appears more vertical than normal, and the lumbar spine, aside from the hollow at the lumbosacral junction, is rather flat. The lordosis of this portion of the spine is more apparent than real, simulated by the already described recess at the upper end of the sacrum. The contours of the strongly contracted long muscles of the back come distinctly into relief. Tenderness is noted along the course of these muscles in more acute cases; it may be very marked shortly after trauma, or insignificant and even absent in more chronic cases (Plate VI, 4).

b. Attitude and Gait.—The poise of the patient is dictated by the position of the lumbar spine. The latter, as a whole, follows the migration of the 5th lumbar body downward. This causes the body to be thrown backward to maintain its position relative to the center of gravity, and the upper portion of the trunk, to regain its balance goes into a slight forward flexion (Turner and Tchirkin[122]). With the increase of the pelvic inclination and the more horizontal position of the sacrum the space between the ribs and the iliac crest appears diminished. The abdomen is pendulous, the hips and buttocks become more prominent, and all these features combine to make the trunk appear abnormally short.

In many instances the gait of the patient approaches a distinct waddle. In milder cases, however, unless a supervening trauma has recently accentuated the symptoms, the awkwardness of posture and gait may be concealed by a natural accommodation of the spine to the static difficulties. (Plate VI, 4.)

c. Nervous Symptoms.—The displacement of the spine produces a great deal of nervous symptoms by mechanical pull upon the plexus. On attempts to lift or strain, patients complain of a dragging sensation in the back with pain radiating down the thigh (Plate VI, 2, 5, 6).

Symptoms on the part of the sympathetic nervous system are manifested by irritative or paralytic conditions of the bowels such as bloating, constipation, and by irritation of the bladder causing frequency of micturition.

7. The Treatment

According to its immediate objective, the treatment might be divided into three headings: (a) the attempt at replacement; (b) the support of the relaxed lumbosacral junction by external means of splinting; and (c) the operative fixation.

All treatments, however, must center ultimately in immobilization and stabilization of this junction. The merits of the respective methods depend upon their ultimate ability to stabilize the spine.

a. Replacement.—Wilson[135] reports a number of attempts to reduce the displaced vertebra. That a true replacement is ever effected appears extremely doubtful, though in a number of cases in which a manipulation was carried out there followed an immediate cessation of the excruciating, radiating pain, especially the type radiating into the perineal and rectal regions.

The manipulation starts with pelvic traction and countertraction at the head and this is followed by an attempt at manual reduction. The x-ray pictures taken did not show that a true reduction had been accomplished (Wilson[135]). Nevertheless the treatment of traction and countertraction in bed is to be considered for its effect upon radiating pain in acute cases.

b. Immobilization by External Means.—In chronic cases with moderate subjective symptoms, or in cases recently accentuated by supervening trauma but not offering severe enough symptoms to make recumbency and traction necessary, immobilization of the sacrolumbar junction is to be attempted by means of external splinting. This is best carried out by means of the plaster of Paris jacket which must include the thighs and must reach well above the lower costal margin, preferably as high as the mammillary level. It must be provided with shoulder straps to hold the upper portion of the back and to control the shoulders. This will give relief in a number of cases and will allow the recent ligamentous strain to return to a state of quiescence. Concerning the permanency of results after conservative treatment by recumbency or immobilization the objection can always be made that such a back continues to remain susceptible to trauma and disability and that the patient has to observe forever great restrictions in his routine life.

c. The Operative Treatment.—It is upon these grounds that exception is taken in many quarters to the conservative treatment of spondylolisthesis. It is Albee's[2] opinion that the condition is not controllable by splinting methods, and others (Hibbs, et al.) likewise believe that little can be accomplished by the use of plaster casts or braces. However, the conservative method has a distinct place in cases with moderate symptoms, in others who are poor operative risks, and finally in cases with recent traumatic exacerbation.

The operative treatment offers relief in chronic cases, and while not placing the spine in condition of normal resistance, yet it gives a definite and lasting degree of stability to the lumbosacral junction.

A strong graft inlaid in the spinous processes of the lower lumbar vertebrae and carefully incorporated into the posterior surface of the sacrum affords a firm immobilization, especially since the large and strong spinous processes of the 3rd, 4th, and 5th lumbar vertebrae facilitate easy and strong anchorage for the inlay graft (Method Albee[3]).

Albee's operation consists essentially in the fitting of an angulated tibial graft into a groove in the sacrum, anchoring the graft into the lumbar vertebrae. It is firmly secured by means of bone pegs, and held by strong kangaroo sutures.

In the technic of Hibbs the lumbosacral and lumbar articulations are reamed out and autogenous bone bridges are prepared to be laid across the gap between the neural arches. The technic is identical with that applied for tuberculosis of the spine and other conditions requiring fusion. The writer has found it a very useful and reliable method.

8. Pseudo and Pre-spondylolisthesis. Synonym: Congenital Hollow Back; Horizontal Pelvis

a. Pseudospondylolisthesis.—The characteristic feature of the so-called pseudospondylolisthesis is that, in contrast with the true spondylolisthesis, there is no real disalignment between the upper surface of the sacrum and the body of the 5th lumbar vertebra. There is a distinct increase in the angle of inclination of the pelvis due to the forward tilting of the sacrum, so that the latter occupies a more horizontal plane. In contrast with true spondylolisthesis this condition is comparatively common. The abnormal lordosis of the lower lumbar spine and the horizontal position of the sacrum produce an increased forward shearing stress at the lumbosacral junction, and consequently a greater degree of strain rests upon the ligamentous apparatus safeguarding the alignment between bodies and neural arches of the 5th lumbar vertebra and the 1st sacral segment. Next to the anterior longitudinal ligament the greatest share in holding the alignment between these segments is assumed by the iliolumbar and lumbosacral ligaments. The iliolumbar ligament especially, running from the lateral process of the 5th lumbar to the crest of the ilei, is placed under abnormal tension in cases of increased lordosis where the forward shearing strain of the lumbar spine tries to force the 5th lumbar vertebra forward. To resist this tendency is the function, not only of the anterior longitudinal, but also the iliolumbar ligament (VonLackum,[126] Lowman).

Such a displacement, however, cannot actually occur as long as there is no corresponding displacement of the sacrolumbar articulation, or a break in the continuity of the 5th lumbar neural arches, as we find it in the true spondylolisthesis (Plate VI, 2, and Plate VIII, 1a).

Herein lies the essential difference between the spondylolisthesis proper which is an anatomic anomaly and the so-called pseudo or pre-spondylolisthesis (Plate VI, 3) (Plate VIII, 1b).

The symptoms existing in the latter condition are all referable to strain of the ligaments of the sacrolumbar junction. In acute cases there is considerable muscular rigidity, the long muscles of the back coming into strong relief, and movement is restricted in all directions, especially anteroposteriorly.

b. Under the term of **Pre-spondylolisthesis** Whitman[131] of New York describes cases of strong lordosis, assuming that the condition represents an initial stage of true spondylolisthesis. The term seems to be unfortunate because, as Glasewald[47] points out, it does not signify a natural pre-spondylolisthesis stage but quite another condition. These patients show nothing of the classical signs of spondylolisthesis; namely, the shortening of the abdomen, the moderate lordosis, the perpendicular direction of the sacrum, and the step or recess at the sacrolumbar junction. Above all, the most characteristic feature of spondylolisthesis, namely, the forward displacement of the 5th lumbar body, is missing. It does not appear probable that such a lordosis may lead to true slipping of the 5th lumbar without such definite anomalies of development as would make a displacement of this type possible. It would seem better, therefore, to remove these cases of abnormal shearing stress from the group of congenital deformities and to class them rather under the mechanical strains to which they are predisposed by certain anatomic variations. In a number of cases of our own observation, we have not been able to observe the development of a true spondylolisthesis from a condition of abnormal lordosis and increased forward shearing stress at the lumbosacral junction.

9. Author's Statistics

Of thirteen cases of true spondylolisthesis treated, eleven showed peripheral symptoms; ten were treated conservatively and three, operatively. In four of the conservatively treated cases operation was indicated but not accepted; the other six showed a fair amount of improvement, enough to allow the patients to carry on their occupations.

The results in all of the operated cases were good; there was complete relief of symptoms.

III. CERVICAL RIBS

1. Historical

It seems that our first knowledge of this condition dates back to Galen (200 A.D.). The earliest authoritative description of the condition is contained in an article of Hunauld[61] which appeared in 1842. A complete knowledge of the condition and of its clinical significance, however, has only been accumulated since the lâtter half of the nineteenth century. Pilling[99] collecting the cases in the literature up to 1894 was able to compile 139 cases, of which number only 9 had been recognized during life. Tillmann[120] in 1895 finds already 26 cases diagnosed, of which number three, including one of his own, had been operated upon.

Probably the most classical monograph on the subject is the one by W. W. Keen[70] which appeared in 1907. Since then the literature on cervical ribs has become very extensive, though not always enlightening, as much contradictory evidence is contained in the different contributions (Honeij[59a]).

The x-ray has been of inestimable value for the early recognition of the anomaly and for the evaluation of clinical symptoms.

2. Pathogenesis

The cervical rib is a numerical variation of the spine, and in particular a caudal assimilation of the cervical spine to the dorsal, in the meaning of Boehm's[18] and Putti's[100] classification.

Many theories have been advanced which bear upon the cause and pathogenesis of this numerical variation. Possibly that of the Leyden anatomist, Rosenberg,[106] is the most attractive. He points out that the spine, phylogenetically, as well as ontogenetically, passes through a reduction of the presacral segments by a process of transformation, operating at both ends. The one working at the caudal end aims at the transformation of sacral segments into coccygeal, lumbar into sacral, and lower dorsal into lumbar; the other working at the cranial end and caudally directed, has a converse tendency, namely, to assimilate the lower cervical to the upper dorsal segment. Both processes of transformation are imagined to meet in the middle of the spine which is, therefore, considered the most conservative and stable segment. From the viewpoint of Rosenberg, therefore, the 7th cervical rib would represent an atavistic phenomenon, while the sacralization of the 5th lumbar as well as the absence of a 12th rib would present itself as a futuristic variety.

Another point in pathogenesis is brought to attention by Bardeen.[8, 9] According to his view the supernumerary rib is a relic of a disturbance in the normal descent of the shoulder girdle. On the basis of the embryologic studies of Rosenberg, Bardeen could prove that the lower extremity which is first located opposite the lumbar spine proceeds caudally in its development to reach its definite place in the 6th fetal week, so that during this period the presacral spine ontogenetically passes through a process of lengthening. Similarly, he finds that the upper extremity from a much more cranial position wanders caudally during embryonal development. But it is still a question whether this descent of the upper extremity is a concomitant or a causative event in relation to a remaining cervical rib, since the costal element of the 7th rib is already established before the upper extremity has finished its downward migration. Be this as it may, the observations throw light upon the question why variation of the pectoral arch, i.e., the shoulder girdle, are so frequently combined with similar variations in position of the pelvic arch, and why concomitant anomalies are often found in both cervicodorsal and the lumbodorsal region.

It has been estimated that only 5 to 10 per cent of the cases of cervical rib established by the x-ray picture are accompanied by symptoms. Therefore, an additional, superincumbent cause must necessarily be assumed, since at least a very great majority of the cases in which this anomaly exists, shows no symptoms whatsoever.

Trauma and strain are the usual factors that bring about the manifestation of clinical symptoms. Twisting of the arm, the pressure of a rifle, compression of the shoulders by the strap of a knapsack, and like circumstances have been variously given as causes. In other instances it is occupational strains, the throwing of a ball, writing, piano playing, etc., which are held responsible. In a considerable number of cases the first symptoms appear during a period of ill health, for instance, in anemia, chlorosis, or general debility following wasting diseases. In such cases, aside from a generally weakened disposition, the wasting of the fat cushions at the neck may be of importance.

3. Pathologic Anatomy

a. Classification.—According to the stage of development Gruber[53] distinguishes four degrees of cervical rib (Plate VII, 4): (1) a simple enlargement of the costal element not extending beyond the lateral dimensions of the transverse process; (2) a blunt projection of the costal element 4 to 5 cm. in length; (3) a true rib extending far enough to articulate with the 1st rib or even attached to the sternum by a ligamentous band; (4) a complete rib. A complete cervical rib has a vertebral as well as a costosternal articulation, the latter joined to the sternum by the costocartilaginous portion. When a complete cervical rib is developed the 1st dorsal usually assumes the character of the 2nd dorsal rib.

b. Description.—The supernumerary rib, unlike a normal rib, becomes broader the greater its distance from the spine, and the free anterior end often forms a tumor which is palpable in the lateral triangle of the neck. A fat tumor appearing in this triangle is described in cases of rudimentary cervical rib (Voelcker[124]).

In growth the cervical rib represents an independent unit equivalent to the dorsal rib. Forward elongation is not procured by the primary ossification centers near the vertebrae but by independent growth of the distal end. The most frequent site of a cervical rib is at the 7th cervical vertebra, that is, at the point of transition of the cervical to the dorsal spine. Only rarely do we find cervical ribs of the 6th vertebra and only in one of the cases reported a cervical rib was found above that level (Voelcker[124]).

In general the imperfect cervical rib of the first type is much more common than the completer forms which are attached to the sternum (Plate VII, 1). The incomplete type of the 2nd degree which reaches beyond the transverse process ends either free in the tissue or is attached in some way to the 1st thoracic (Plate VII, 2). In the third type in which the rib extends for a considerable distance, as far as the cartilage of the 1st rib, it possesses a complete body and may be united directly or by means of ligaments to the cartilage of the 1st rib (Plate VII, 3). In the fourth, or complete type, the rib reaches the manubrium of the sternum and its vertebral attachment represents a complete joint corresponding in mobility to that of the dorsal rib. Sometimes a longer or shorter exostosis is seen running upward from the 1st rib to unite with the cervical rib; not uncommonly this projection causes a palpable tumor at the lateral triangle of the neck.

When a cervical rib is developed on both sides one is always found higher and better developed than the other and it is usually this side which produces symptoms.

According to the degree of development LeDouble[78] recognizes the following varieties: the complete cervical rib extending from the 7th cervical vertebra to the manubrium is, in all its parts, independent of the clavicle as well as the thoracic rib. In another group the cartilaginous portion of the cervical ribs is fused with that of the 1st thoracic. In another variety the midportion of the cervical rib is substituted by fibrous bands.

Among the more incomplete types LeDouble distinguishes one variety in which an anterior and a posterior portion exists independent of each other; and in another group an independent posterior stump is articulated with the

PLATE VII

Fig. 1.—Bilateral cervical rib: first degree. Symptomless.

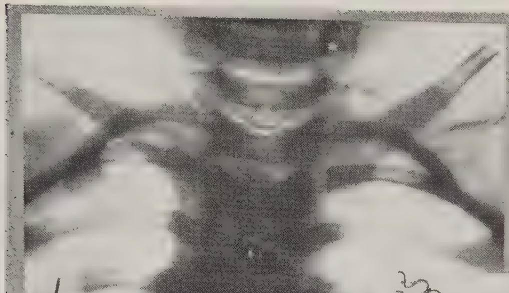
Fig. 2.—Bilateral cervical rib: second degree. Cyanosis and sensory disturbances of finger tips of right hand.

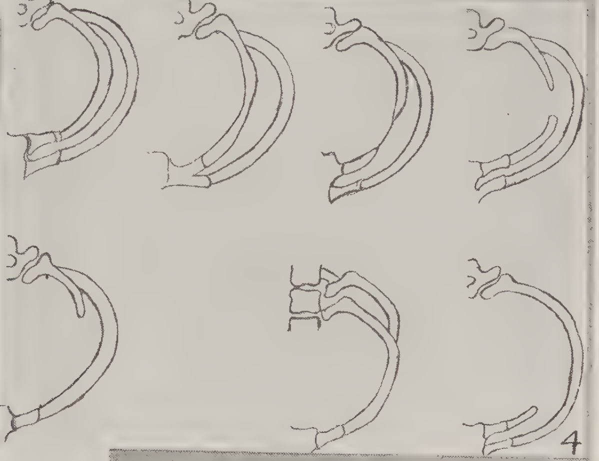
Fig. 3.—Unilateral cervical rib. Third degree: associated with congenital scoliosis and fusion of cervical spine. Symptomless.

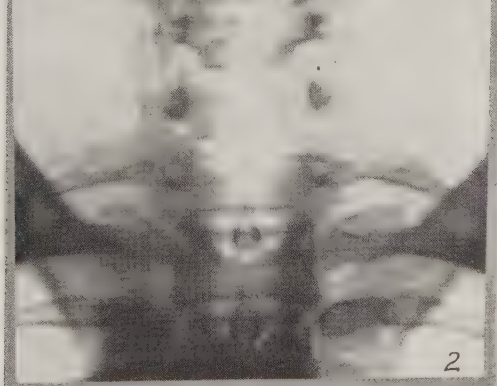
Fig. 4.—Gruber's classification of cervical ribs.

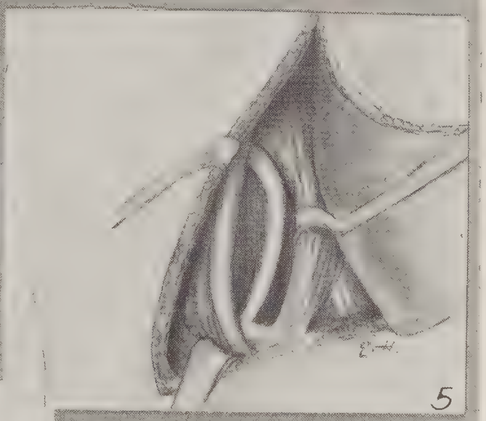
Fig. 5.—Prentiss approach for removal of cervical rib (courtesy Dr. H. J. Prentiss).

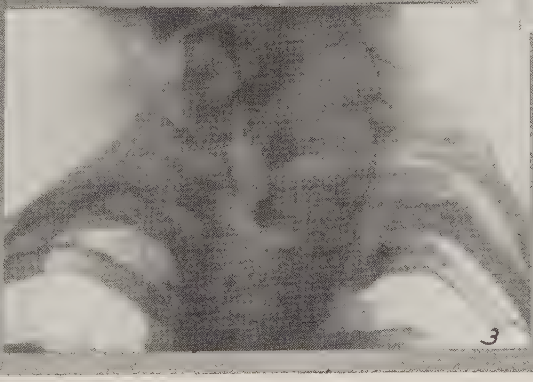
Fig. 6.—Operation of Adson and Coffee.











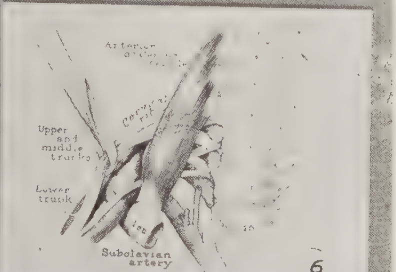


Fig. 6.—Illustrating the compression not only of the sub[illegible] and the lower trunk, but irritation of the entire brachial p[illegible] scalenus anticus against the completely formed cervical rib. (Mason)

PLATE VII

1st thoracic rib, or fused or bound to it by fibrous tissue. Exceptionally only, an anterior stump alone develops.

c. The Relation of the Cervical Rib to the Neighboring Structures.—

(1) *The Artery.*—If the cervical rib is short, plexus and vessels do not pass over it but in front of the anterior end. Halberstma[56] estimates that up to a length of 5 cm. the rib does not come in contact with these structures; when it is longer the artery passes over it; if it is of considerable length both artery and nerve pass over it and the chest cavity appears lengthened by the addition of this rib. The artery then rises higher than normal to assume a more acute angle downward after crossing the rib. At this point signs of constriction may be noted in the sharp bend of the artery. Often there is marked compression of the vessel between the rib and anterior scalenus muscle. A sharp kink of the artery has been repeatedly demonstrated at operation (Weissenstein[130]). Especially in respiratory movement the rib exerts a pressure against the artery. In a case of Borchard's, traction upon the hand downward caused complete compression of the artery between the scalenus muscle and the rib. Similar symptoms were observed by de Quervain[101] in connection with the up- and downward movement of the shoulder. When the rib is removed at operation it is observed that the artery sinks back into fat tissue; the tension and with it certain symptoms become relieved. Such an occurrence has been observed by Ramsey and Keen.[70] From the relation of the rib to the scalenus muscle and the artery one will understand the possibility of grave circulatory disturbances, such as pressure thrombosis, embolism, which will be discussed later among the clinical symptoms.

(2) *The Plexus.*—It is less easy to explain the nervous symptoms upon the basis of pathologic conditions. Angulation cannot very well be blamed because the brachial plexus rises in the neck above the level of the cervical rib and its course is from above and inward to downward and outward. Nevertheless, a certain upward pressure may be exerted by the abnormally long thoracic cage, and since this pressure is being constantly repeated during inspiration or upon movement of the shoulder it has a considerably traumatizing effect. Besides, cases are reported in which the nerves are found flattened out by the upper surface of the rib (Coote,[31] Warren[129]).

Direct compression of the lower cord of the plexus by fibrous bands which pass from the tip of the rudimentary rib under the plexus were found in a case described by Thomas and Cushing. This band represented a forward continuation of the imperfectly developed cervical rib. Furthermore, the removal of the offending rib is almost always followed by a relaxation of the plexus and often by a relief of the nervous symptoms. That the lower cords of the plexus are much more frequently involved than the upper ones must be clear from their anatomic situation, since it is the upward pressure of the cervical rib which lifts the cord and produces the symptoms. There is also a mechanical effect exerted by the overlying clavicle. If the rib is long and reaches well forward, then the space between it and the clavicle may become narrowed. An instance is recorded by Schnitzler[110] in which the anterior end of the abnormal rib approached so closely to the clavicle that the former acted as a fulcrum, so that when the shoulders were thrust backward the inner end of the clavicle became dislocated.

(3) *The Vein.*—Murphy[93, 94] pointed out that the subclavian vein usually escapes compression. This is due to the fact that this structure as a rule lies a considerable distance below and in front of the artery, and this position saves it from being compressed between the rib and the anterior scalenus muscle. This accounts for the absence of edema in the arm in nearly all cases.

(4) *The Muscles.*—Where the rib is well developed there is always to be found an intercostal muscle. The situation of the scalenus anticus is often altered so that it inserts into the anterior extremity of the cervical rib. This indicates the early date at which the congenital anomaly is preformed (the 1st month). The medius and posticus may either pass the cervical rib or be inserted both in the cervical and the 1st and 2nd dorsal ribs. This leaves the subclavian artery between scalenus and rib while the nerve plexus comes down from above and behind the artery between anterior and medius scalenus muscles.

(5) *The Pleura.*—We mentioned before that the thoracic cage is lengthened by the presence of the cervical rib and that the pleura rises up much higher in the neck; often the dome of the pleura is so closely adherent to the rib that it becomes difficult to separate the two structures.

d. The X-ray Findings.—One is often struck by the great discrepancy between the size of the cervical rib and the degree of the clinical symptoms. Honeij,[59a] who studied a series of cases of apparently absent cervical rib with positive symptoms, found that, in these instances, a large irregular transverse process of the 7th cervical vertebra existed, with a narrow space between it and the thoracic rib, a fact which he believed explains the nerve symptoms. On the other hand, there are cases of true cervical rib where the intercostal spaces are so wide that there is no pressure upon nerves or blood vessels and no clinical symptoms develop.

4. Frequency

In most cases it is reported that symptoms appeared between the ages of twenty to thirty years. While this is the usual age period, cervical rib has been discovered in various ages from six months up. As a rule, however, symptoms do not become manifest until in adolescent life and sometimes much later. It is asserted that it occurs most frequently in females (Streissler[116]). Keen's statistics show thirty-five female and twenty-five male patients. In Howell's[59b] series of sixteen cases fourteen were women, and all of the sixteen cases were under thirty.

That the condition has become more frequent since the advent of the x-ray examination is obvious. Ehrich[40] (1895) still believed that the cervical rib is much less frequent than the lumbar rib.

The cervical rib occurs more frequently bilaterally, according to Keen in about two-thirds of all cases, a similar ratio being given by Henderson. It is probable that even more than two-thirds of the cases are bilateral if one includes the smaller enlargements of the costal element of the lateral process of the other side. In a case reported by Karg (1895) and in cases reported by Putti[100] and others, formation of two cervical ribs, at the 6th and 7th cervical vertebrae, of the same side was observed.

5. Latency

The same feature of retardation and latency of symptoms which we found peculiar to other congenital deformities is also encountered in cervical ribs, and it requires some explanation. Among forty-two cases reported in the literature, symptoms appeared at ages under sixteen in six, from fifteen to twenty in fifteen, from twenty to thirty in eight, from thirty to forty in eleven cases. The majority of cases does not produce symptoms until after the fifteenth year of life. Grisson[52] reports a case of bilateral cervical rib in which the symptoms, consisting of tire and paresthesia, did not appear until the age of forty-seven. The late manifestation at the time of puberty may be ascribed to the more rapid growth of the rib in adolescence (Grisson). For the appearance of symptoms in later life a number of other factors may be responsible, for instance, the diminished elasticity of the artery due to arteriosclerosis causing more marked reaction to pressure, or the loss of tone of the muscles, or the habitual drooping of the shoulder, or the development of a senile kyphosis. Other authors explain the latency of symptoms on the ground that the ossification of the transverse process does not begin until puberty and is not complete until the age of twenty-five, and that, as a rule, a cervical rib tends to become progressively larger, less movable, and more apt to produce pressure symptoms between the ages of fifteen and twenty-five (Babcock[7]).

6. The Clinical Symptoms

a. Classification.—Following the classification of Keen[70] the symptoms are best grouped as follows: (1) local symptoms such as tumor, or pain on pressure; (2) nervous symptoms: pain and paraesthesia; (3) vascular symptoms: pulsation, gangrene, edema, thrombosis and aneurysm; (4) muscular symptoms: wasting of muscles, loss of power, tire, etc.

As has already been stated, there is no parallelism between the development of the cervical rib and the extent of the symptoms. Cases with no demonstrable cervical rib may produce symptoms, while on the other hand definite, well-developed cervical ribs may remain symptomless. It is not the extent but rather the relation of the cervical rib to the 1st dorsal rib and the structures of the neck which determines the symptoms.

(1) *Local Symptoms.*—The cervical rib may present itself as a tumor in the neck, either palpable or visible, or both. It is usually found one or two finger widths above the middle of the clavicle, and presents itself as a more

or less rounded and apparently immovable mass. Above the tumor, higher in the neck, running obliquely from above and inward to downward and outward, there is a visible and palpable pulsation caused by the subclavian artery, and such a pulsating vessel should always arouse suspicion of a cervical rib. A little above this tumor there is a point of tenderness which marks the location of the brachial plexus.

(2) *Nervous Symptoms.*—All nervous and vasomotor symptoms are either pressure phenomena or pulling or traction effects on the part of the cervical rib.

In early stages of pressure the patient complains of paraesthesias of the arm and forearm and especially so in the field supplied by the ulnar nerve. Change of position of the arm increases or diminishes the symptoms; elevation of the shoulder usually relieves nerve pressure, and the patient is more comfortable at night with the arm elevated above the head. Depression of the arm aggravates the pain. The premonitory symptoms of nerve pressure are tingling and numbness; later, as the pressure becomes more severe, anesthesia and paralysis follow. The pain, now of definite paroxysmal type, is no longer relieved by change of position. It usually starts in the neck and radiates downward in the arm sometimes as far as elbow and hand, usually keeping close to the distribution of the ulnar, less frequently to that of the musculospiral nerve. Muscular exertion, or hard work increases the pain; it often appears to be worse in the winter than in the summer. It is preeminently influenced by exertion and cold. In distribution it indicates involvement of the 8th cervical and 1st dorsal roots (Howell[59b]). Gordon[49] reports an unusual case with sensory loss of the 5th and 6th cervical roots. Sometimes there is a diminution or entire absence of electrical reaction and in the more advanced cases one finds reaction of degeneration.

In a number of instances symptoms point to the involvement of the sympathetic nervous system. In a case reported by Hirsch[59] there was profuse sweating, coldness and dryness of the skin. Gordon[49] reports an instance of rapidity of the pulse, increased heart action, excessive subclavian pulsation and dilatation of the artery, suggesting not only involvement of the 7th, and 8th cervical and 1st dorsal roots, but also of the inferior cervical sympathetic ganglion and its branches. Fürnrohr[45] records an instance of irritative sympathetic eye symptoms associated with cervical rib; widening of the palpebral fissure, proptosis of the eye, widening of the pupil. Hoarseness also has been noted in cases of cervical rib, but whether as a symptom of irritation of the recurrent laryngeal nerve, or due to a local affection of the throat has not been determined.

(3) *Circulatory Symptoms.*—

(a) Ischemia. The change in circulation involves, for reasons already mentioned, much more the arterial than the venous systems. If there is compression of the subclavian artery one notes that the return of circulation on the affected side is slow. The hand remains blanched, wrinkled and cold, and suggests the pallor seen in Reynaud's disease. There is usually no evidence of venous stasis. If the pressure upon the artery is continued, it may lead to an obliterating endarteritis and in some cases be followed by gangrene, where the occlusion of the artery develops more rapidly. If it develops more slowly one may expect a collateral circulation to become established. Variation of posture of the shoulder blade and arm has a marked effect upon the pulse in some cases similar to its effect upon the nervous symptoms. On raising of the arm the pulse returns together with relief of pain. The same effect can be noted by deep inspiration.

(b) Aneurysm. A diagnosis of aneurysm should always be made with a great deal of care; it should only be definitely accepted when the dissection or exposure of the artery actually reveals the presence of this condition. The broad pulsation which one feels as well as the visible lateral extension may be deceiving, being due to the flattening of the subclavian artery. There may also be a bruit extending in downward direction and more marked when the shoulder is depressed, giving the erroneous impression of an aneurysm.

(c) Edema. As already stated edema is uncommon in cervical rib (Murphy,[93, 94] Keen[70]). Keen in his review of the literature found only four cases of edema.

(d) Thrombosis. Thrombosis occasionally results from a constriction of the artery and interference with the blood current. A severe trauma to the artery in its exposed position may produce thrombosis with distal gangrene.

Reports in the literature of thrombosis from cervical rib are numerous (Cooper,[30] Adams, Ehrich,[40] Gordon,[49] Keen,[70] Fischer,[43] Grisson[52]). Schiassi[108] cites two cases of thrombosis of the subclavian artery. In one case the removal of the cervical rib was followed by a thromboendarteritis of the subclavian artery for a long distance with subsequent gangrene of the limb. In cases reported by Keen and Babcock[7] a return of pulse was observed following the operative removal of the cervical rib.

The extent of thrombosis varies. Sometimes it may involve the arteries of the forearm only, at other times, also the brachial, or axillary and subclavian portions. The progress of thrombosis can be followed from day to day as it wanders upward to the axilla. The pulsation of the artery is absent and the artery itself is felt as a hard and solid cord. These are the cases in which pulsation fails to return after removal of the rib. Usually after a time a collateral circulation is established but often it is so inadequate that gangrene becomes unavoidable. Bowlby[21] pointing out to the obscure pathogenesis of the obliterating arteritis in the upper extremity is one of the early observers who established a relation between pressure of the "exostosis" upon the subclavian artery and the secondary endarteritis (1888).

(4) *Muscular Symptoms.*—The muscles involved in secondary atrophy from nerve compression are particularly the intrinsic muscles of the hand and those of the thenar and hypothenar eminences. Some of the diffuse atrophy of the whole arm may be due to disuse, especially as certain movements of the arm remain suppressed because they induce neuralgic pain. The muscles of the

arm on the affected side thus undergo a gradual wasting and shrinkage. Aside from the intrinsic muscles of the hand the muscles of the forearm also show some loss of power. The arm and hand loses much of its usefulness especially in the execution of the finer finger movements, due to the loss of the intrinsic muscles. Several observers have noted and described ataxias. Howell[59b] found in recent cases a reaction of degeneration.

(5) *Scoliosis in Cervical Rib (Plate VII, 3).*—Schoenbeck[111] (1905) collected from the literature a series of cases in which the formation of a cervical rib was associated with scoliosis. The convexity is usually directed toward the side of the cervical rib, or, if the rib is developed on both sides, it points to the side of the larger rib. The scoliotic curve usually reaches from the 6th cervical to the 4th dorsal vertebra. It is, as a rule, accompanied by a high scapula on the convex side. Considering the variability in size, form, and vertebral connection of the rib, we can understand why scoliosis does not always accompany this anomaly. If scoliosis is present, it is characterized by its high location, its extreme rigidity, the accompanying displacement of the scapula, the asymmetry of the neck—all features which suggest the congenital character of the curvature. Such a scoliosis should always arouse suspicion that the cervical rib is present. Often, however, scoliosis develops primarily from a supernumerary vertebra. Drehmann,[35] in a most instructive treatise on scoliosis and cervical rib, reports an instance of a fully developed cervical rib joined to a supernumerary vertebra on the convex side. In this case there were also other anomalies present: the 1st dorsal vertebra carried two ribs, one corresponding to the normal vertebra and one to the rudimentary one. The 12th dorsal also carried two ribs. In another case there was a division of the 7th cervical vertebra with an interpolated wedge-shaped 1st dorsal rudiment on the convex side carrying a rib. Such cases very forcefully illustrate the point that a cervical rib often exists as a symptom of a more generalized spinal anomaly or developmental arrest, leaving its traces in several, if not in all, sections of the spine. The association of the cervical rib with other developmental anomalies is of further significance. Marburg[86] and Oppenheim[97] describe developmental anomalies of the spinal cord associated with cervical rib. Progressive muscular atrophy of the cervicobulbar type associated with cervical rib is reported by Spiller and Gittings.[115] Levi[80] found a cervical rib in a case of multiple sclerosis. Bassoe emphasizes the fact that true syringomyelia is not infrequently associated with cervical rib. There is, in short, increasing evidence to show that cervical rib, more often than not, is merely a symptom of a more generalized and deeper rooted condition of congenital developmental aberrations.

7. Differential Diagnosis

There are comparatively few conditions which require special attention in differentiating them from cervical rib. It is only rarely that arthritis of the cervical spine with radiating symptoms will offer serious difficulty. Off and on, however, one observes cases in which the arthritic symptoms are concentrated in the lower cervical section with points of tenderness to pressure over the transverse process of the 6th or 7th cervical vertebrae. Such cases, as a rule, can be properly identified by x-ray examination.

In subdeltoid bursitis there is a point of semblance in the pressure pain at the shoulder joint, which may be mistaken for the radiating pain of a cervical rib. The point of distinction, however, is the limitation of motion in certain directions and the absence of vascular and sensory disturbances.

Disturbances of the subclavian circulation and pressure symptoms upon the plexus may be caused by other bony tumors which originate in the supraclavicular fossa. Mesnard[90] cites instances of exostoses of the 1st rib producing neuralgic pain in arm and shoulder as well as weakness, coldness, formication. The callus which follows the fracture of a thoracic rib may occasionally be mistaken for a cervical rib. Here the history of trauma as well as the x-ray picture are points of distinction (Boorstein[20]).

Occupational neuroses and neuralgic symptoms of other nature as well as infectious neuritis along the cords of the plexus are more apt to cause difficulties in differentiation. This is especially the case if no definite anatomic anomaly of the 7th cervical vertebra can be made out in the x-ray picture. However, any case of sensory disturbance involving the lower cord and associated with paralysis of the intrinsic muscles of the hand and vasomotor changes suggest the presence of a cervical rib.

Occupational neurosis offers similar neuralgic symptoms, but vascular signs are usually not present, and in infectious neuritis the trophic signs limited to the distribution of the nerve involved are an aid in the distinction of the two conditions. Little difficulty should be encountered in cases of tuberculosis of the cervical spine, or in the rarer cases of spastic torticollis.

8. The Treatment

a. Conservative.—More recent cases should be subjected to conservative treatment before operation is decided upon. This applies especially to cases which yield to change of position; also cases in which the subjective symptoms are elicited by exertion and are subdued by rest, are worth a trial by conservative means. The latter consist in rest combined with massage, electricity, and douches; also in simple hygienic measures, if the patient's general condition is poor.

b. Operative.—The majority of patients, at the time seen, already show symptoms too severe and too inveterate for conservative treatment, the latter, as a rule, having been tried previously without success.

(1) *Indication.*—Murphy[93] believed that all cases should be operated on as soon as diagnosed. The removal of the rib need not prove dangerous if proper care is exercised in dealing with the anatomic structures. Therefore, the indication for the operation must not be made with too much hesitancy. Aside from the neuralgic cases which do not yield to conservative treatment, those showing circulatory disturbances should be selected for operation; if the cir-

culatory changes are severe, especially if gangrene of the tips of the fingers is imminent, then the operation should no longer be delayed.

(2) *Historical.*—The first report on an operated case of cervical rib is that of Coote[31] in 1861. A man of twenty years showing a tumor at the side of the neck since early childhood, developed pain in arm and elbow, flabbiness of muscles, numbness and cyanosis. In this case the operation was carried out by proceeding in front of the trapezius muscle and, pressing the nerves aside, the neck of the tumor was divided and finally removed. After this operation the circulatory disturbance and numbness disappeared. Between 1861 and 1885 only eight operations are recorded, and from 1896 to 1906 only twenty-five. In this whole series the operative mortality was nil. An earlier operative report is that of Fischer[43] (1891) which is of especial interest because it still falls in pre-x-ray days. The patient complained of pain in the brachial plexus, paresthesias in arms and fingers. An incision was made over the palpable cervical rib and by stripping the rib back to the point of the 7th cervical lateral process the tumor could be removed for a distance of 4 cm. and the operation was successful. Dejerine[34] (1903) reports a favorable operative result by the removal of a cervical rib for neuralgic symptoms involving the 5th and 6th cervical nerves, an unusual field of distribution.

Since then reports of successful operation have become more and more numerous. Henderson[58] adds six cases of successful removal of a cervical rib, and other instances are reported by Boorstein[20] and Tubby.[121]

(3) *The Technic.*—There are usually given three routes of approach: an anterior along the posterior border of the sternocleidomastoid muscle, a lateral along the anterior border of the trapezius, and a posterior parallel to the spinous processes of the cervicodorsal vertebrae. The latter procedure should be rejected because it is unanatomic. Of the former two we would recommend the anterior route in which the incision is made along the posterior border of the sternocleidomastoid muscle. As worked out by Dr. H. J. Prentiss (p.c.) this is anatomically the best as well as the safest procedure (Plate VII, 5): one proceeds through the skin and platysma to the deep vaginal fascia of the neck in which the sternocleidomastoid as well as the trapezius muscles are enclosed. The fascia is split at the posterior border of the sternocleidomastoid and the muscle is retracted inward. The infrahyoid muscle fascia bounded by the omohyoid muscle then presents itself; it is retracted downward, and, by blunt dissection, the anterior scalenus muscle is defined to its point of insertion at the supernumerary rib, or the first rib, as the case may be. The plexus is seen to leave the vertebral foramina between the anterior and medius scalenus muscle; the rib is followed up by blunt dissection to the transverse process of the 7th cervical vertebra.

When the accessory rib is reached one usually finds it higher than expected, and, therefore, good care must be taken not to mistake the 1st or true rib for the cervical rib. The rib is often embedded in the scalenus medius muscle. Here the so-called carotid tubercle is a very useful landmark. It is the most prominent tubercle of the cervical transverse processes and belongs to the 6th cervical vertebra. From it one can easily orient oneself as to the location of the cervical rib. When the latter is definitely made out its muscular and ligamentous attachments are divided by sharp dissection so as to leave all the periosteum on the rib; the pleura and the subclavian artery must be carefully protected. The last part of the rib to be freed are neck and head. The 7th cervical root coming out of the intervertebral foramen passes over the neck of the rib at an angle of sixty to seventy degrees; and just in front of the neck runs the vertebral artery with its plexus of veins. The removal of the head and neck, therefore, represents the only danger to vessels and nerves. After the outer portion of the rib has been dissected its attachment is held by forceps and manipulated back and forward until it is possible to dissect the inner portion free, and a clean enucleation of head and neck is performed (Keen). It is toward the end of the dissection, when the rib is freed at its vertebral end, that some hemorrhage is apt to occur; this can be controlled by packing. The greatest danger lies in the proximity of the pleura which is easily injured. If this occurs the hole should be immediately covered by the finger and packed. The periosteum should be left with the rib although in no case has a reproduction of the rib been observed. When the brachial plexus is drawn forward, a certain tension cannot always be avoided, so that severe pain may be felt for several days after the operation and in some cases there may be partial or complete temporary paralysis. Correct technic and gentle handling of the tissues usually prevents such untoward complications. The wound is closed in the usual manner and no drainage is applied. The after-treatment consists in massage of the arm, electricity, passive and active movements and exercises (Henderson,[58] Taylor[118]).

In a recent contribution, Adson and Coffee[1] recommend instead of the resection of the rib, the simpler tenotomy of the scalenus anticus muscle, being convinced that the latter is responsible for the compression of the subclavian artery as well as of the inferior and middle trunk of the brachial plexus. They report five cases operated with complete cessation of symptoms (Plate VII, 6).

IV. DYSOSTOSIS CLEIDOCRANIALIS

1. Definition and Classification

The deformity was first described and named by Pierre Marie[87] in 1897. Since then reports on about one hundred cases have found their way into the literature. As the name implies, the condition is characterized by defects in the process of ossification of the clavicle and the cranium. This, however, is not the only feature. Murk Jansen[64] describes a syndrome consisting in retarded development of the frontal bones with persistence of a large fontanelle, and in shortening of the intermediate and terminal phalanges of fingers and toes as well as in the defective development of the clavicle. He applies to this condition the name of "dysostosis cleidocranialis digitalis."

Two types of the deformity should be distinguished: in the first the defect of the clavicle is the only symptom and there are no concomitant deformities of skull and other structures. In the second group, which embraces the greater number of cases, maldevelopment and deformity of clavicle and skull are associated with other defects and anomalies. Cases have been observed with absence, not only of the clavicle, but of the shoulder blade as well; these cases belong less in the dysostotic class than in that of true aplasias or agenesis of extremities. So far as the clavicle is concerned Heinecke[57] distinguishes types of congenital kinking or separation with a pseudarthrotic gap between the fragments filled with connective tissue; or a partial defect of one, and usually the acromial end, substituted or not, by fibrous bands; or, finally total defects of the clavicle. In reviewing the cases in the literature up to 1908 he also mentions a number of other anomalies of the skeleton which accompany the classical symptoms of the condition. These complications are cervical ribs, marked depression of the sternum over the xiphoid process, chicken breast, impingement of the ribs at the costocartilaginous end, and scoliosis. Other congenital anomalies described are subluxation of the head of the radius (Vandenbusch), the enlargement of the end phalanges of the fingers and the curving of the nails (Kapler).

2. Pathogenesis

The deformity is basically a primary developmental aberration (Heinecke[57]). All authors emphasize that the defect originates very early in embryonal life, as far back as the beginning of ossification of the skeleton, that is to say, within the first few weeks. The clavicle develops first as a membranous preformed bone, appearing already in the seventh week as the first part of the bony skeleton, at the same time when an ossification center appears in the mandible. The ossification of the clavicle begins in the middle and progresses rapidly to both ends; epiphyses appear at the sternal end and these show ossification centers in the fifteenth year. The acromial end has no separate ossification center, but ossification progresses toward the acromion from the center in the diaphysis.

The cranium is also membranous preformed and its ossification begins in the second fetal month, a little later than that of the clavicle. It is possible that we are dealing in this deformity with an atavistic relapse. We know that the carnivorous and ungulated animals have either no clavicle or only a rudimentarily developed one, but have a strongly developed coracoid process. With the gradual reduction of the latter, the clavicle becomes larger, and such animals as use the anterior extremities more freely have a better developed clavicle.

Concerning the immediate pathogenesis of the condition several theories are being advanced: (1) amniotic bands, (2) heredity, and (3) injury or disease. Amniotic bands are probably not at work according to Maas'[85] investigation on four hundred embryos; neither can intrauterine fractures be considered as a cause. The fractures of the clavicle at birth are not uncommon, but they always unite. There remains then only the constitutional factor of heredity to be considered. Kirmisson believes that a general systemic element is at work in the formation of this deformity, and that too much emphasis should not be laid in pathogenesis upon the mechanistic side. Such developmental arrest and defects as are presented by this deformity reach too far back into early embryonal life to be ascribed to localized mechanical factors, as intrauterine fracture or the pressure of amniotic bands. Jansen's[65] theory although in principle also a mechanistic one, revolves around the inhibiting influence of amniotic pressure upon the organism as a whole. The dysostosis cleidocranialis is, according to him, one of the conditions which results from a general increase of amniotic pressure. In this respect the deformity ranks with chondrodystrophy, osteogenesis imperfecta, and fetal rickets. That there is a certain relation between dysostosis and chondrodystrophy is suggested by the transverse flattening of the thorax, the high palate, the deformation of the maxilla as well as the broad phalanges. There are other conditions aside from achondroplasia and dysostosis which are ascribed by Jansen by amniotic pressure, for instance, congenital dislocation of the hip, clubfoot, etc. While it is hard to accept this conception of the amniotic pressure producing so many heterogenous deformities, it is perhaps well for the understanding of such congenital anomalies as the one in point, to appreciate not only the pathogenetic factor as such, but also the particular period in fetal life in which this factor becomes operative. Jansen, with a great deal of plausibility, explains, upon a chronologic basis, different congenital conditions, produced by the same pathogenetic cause. Anencephaly, for instance, he supposes to be a mechanical arrest in a second or third week of intrauterine life; achondroplasia at the fifth or sixth week; mongolian idiocy at the seventh; and dysostosis cleidocranialis in the eighth week of life. However doubtful and speculative this theory may appear, it is a fact that mechanical deformations of the skull which are found in dysostosis are also met with in achondroplasia; there is the same retraction, the same flatness, the same shortening of the tri-basilary bone.

Heredity.—The familial occurrence of the deformity is definitely recognized by all observers. It is especially evident from the reports of Marie and Sainton,[107] as well as from the series of Hultkranz,[60] the latter reporting in his collection a woman of twenty-eight with three daughters afflicted by the same condition. Jansen[65] sees in the consanguinity of the parents an etiologic factor. In one of his cases the mother was a hyperthyroid, the father a dysostotic, and one daughter a chondroplastic, while the son, the patient under observation, presented a combination of achondroplasia and dysostosis cleidocranialis. LaChapelle reports five cases in one family and Blencke[17] reports an instance of a family consisting of mother and three children, all with congenital bilateral defects of the clavicle. In the light of these facts the condition can hardly be considered a deformity caused by localized pressure, fracture, etc. It must be placed into the class of systemic intrinsic deformities, the cause of which lies in early developmental aberration reaching back into the first weeks of embryonal life.

3. Pathology

This congenital anomaly has a peculiar selection for ligamentous preformed bone, namely, clavicle and skull. It involves exclusively the periosteal ossification in contrast to chondrodystrophy in which the enchondral ossification is involved. The systemic character of the deformity appears from its association with other congenital anomalies; besides those mentioned there are the clefts of the bodies of the vertebrae, wedge formations, scoliosis, etc.

The defective development of the clavicle is the most characteristic feature. It is either missing altogether on one or both sides, or the acromial half is missing, or only membranously preformed. As a result there is unusual freedom of the shoulder which can be brought in front of the chest opposite the sternum. The defect is more often partial than total, a bilateral total defect of the clavicle is the exception. The missing portion of the clavicle is usually substituted by fibrous strands. The connection between clavicle and sternum is normal, but the sternal portion of the clavicle appears displaced, assuming an almost perpendicular direction.

Of muscle defects about the shoulder there have been observed a missing clavicular portion of the trapezius, a maldevelopment of the pectoralis major, and the absence of the clavicular portion of the deltoid muscle. The abnormal freedom of the shoulder enables the patient to cross the arms behind the head, to touch the ear with the shoulder, and when one hand is weighted down the shoulder girdle can be depressed much farther downward than under normal conditions. The pathologic changes of the skull may present themselves in various aberrations of the bones of the face, in a high palate, in retardation of the development of the frontal bones and in the large fontanelle. The skeleton of the face appears displaced backward in regard to the brain pan (Jansen), and the base of the skull is pressed in and shortened, the angle between the horizontal and descending ramus of the mandible is more obtuse. All this is accompanied by the smallness or absence of the frontal, maxillary, and sphenoid sinuses. These anomalies in ossification recall to the mind the characteristic growth disturbance of the tribasilary bone which is found in achondroplasia (Schenthauer). The thorax shows the following changes: the chest is narrow, the ribs are curved, more drooping than normal, but there is no rosary or other rachitic changes. The scapula stands high, or appears lifted off the thoracic wall while the acromian and humeral head droop downward, giving the body the aspect of round shouldered posture.

4. X-ray Findings (Plate VIII, 3, 6)

X-ray examination shows that the clavicle which is palpable under the skin is largely cartilaginous, the defect in the clavicle being filled out pre-

PLATE VIII

Fig. 1.—(After H. Glasewald.) A. True spondylolisthesis. B. Pseudospondylolisthesis. Horizontal sacrum.

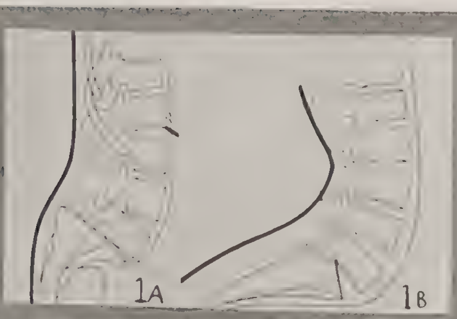
Fig. 2.—Dysostosis cleidocranialis—unilateral. (Brothers are the patients shown in x-rays 3 and 6. Note shape of heads.)

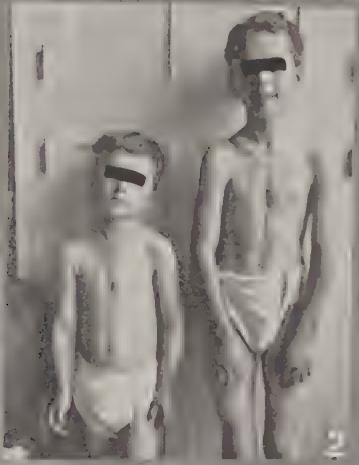
Fig. 3.—X-ray of younger brother Figs. 2 and 4. Rounded ends of defective clavicle.

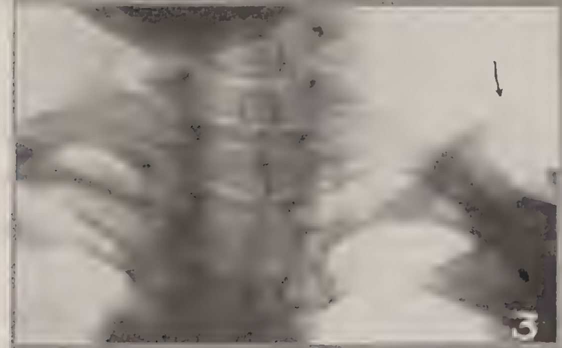
Fig. 4.—Spondylolisthesis. Marked peripheral symptoms, motor and sensory of both lower extremities. Unbenefited by prolonged traction.

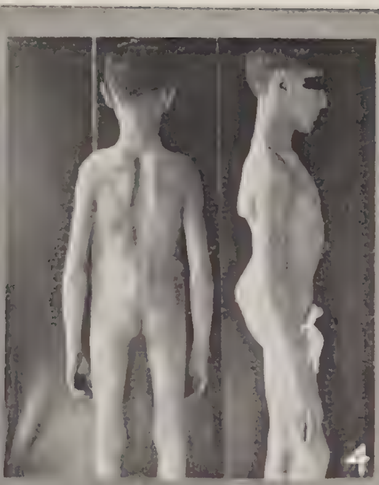
Fig. 5.—Patients of Fig. 2. Abnormal mobility of affected shoulders.

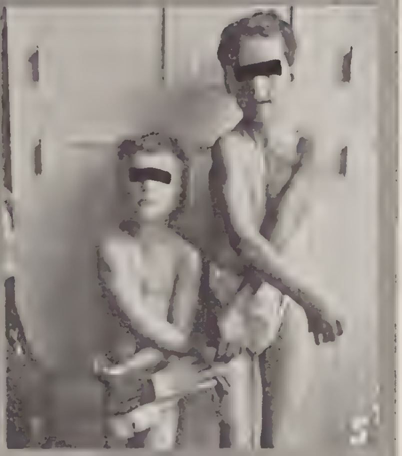
Fig. 6.—X-ray of older brother.











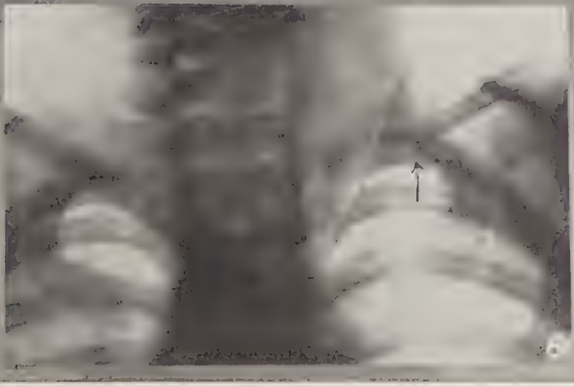


PLATE VIII

sumably with fibrous tissue, the acromial end of the clavicle usually being the one which appears missing. Changes in the position of the shoulder blade can likewise be made out in the x-ray picture, and also the deformation of the thorax and the anomalies of the skull. The broad forehead, the high palate, the wide sutures, and the great interorbital distance is evident in the skiagram (Hultkranz[60]). Occasionally a shadow of a connective tissue strand is seen running from the defective clavicle to the coracoid process.

5. Clinical Symptoms

All cases are characterized by the narrow shoulder, and the extreme mobility of the shoulder joint enabling the patients to bring the shoulders together in front of the chest. The function of the arm is never impaired (Plate VIII, 2, 5). Changes in the skull appear clinically in the persistence of the fontanelle, the prominence of the frontal bone, the protrusion of the mandible. One also notes the increased transverse diameter of the skull and the high palate. Combinations of achondroplasia with dysostosis have been cited repeatedly in the literature. Aside from the cases of Jansen the one reported by Montanari[91] is of interest. The patient was a boy of eighteen, short of stature, of short extremities. The bone showed no changes of the epiphyseal cartilage as in achondroplasia, but appeared twisted, short, contorted, especially the forearm. The long bones had a heavy cortex and a much reduced medullary canal. The clavicle although well ossified, appeared much less voluminous than normal, and was aplastic in the outer third. As a rule, the long bones on the dysostotic appear peculiarly fragile and of diminished elasticity in contrast to pure achondroplasia where volume and form of bone is especially noticeable for its heaviness and thickness. In a case reported by Durant the dysostosis was combined with symptoms of periosteal dysplasia. The cranium appeared little altered in shape, but the consistency of the skull was diminished due to the membranous persistence of the lacunae and fontanelles. The patient presented numerous features of true dysostosis, showing, aside from the classical symptoms, also deformation of the sternum and deformity of the terminal phalanges of fingers, a type of case considered by Jansen a mixture of achondroplasia and dysostosis cleidocranialis digitalis.

6. Treatment

Very little is to be said about the treatment. Since the defect does not produce any loss of function in the shoulder nor any loss of power in the arm, but renders the motion of the shoulder rather more free than normal, no treatment is necessary, excepting to support the shoulders and to keep them from drooping forward. This can readily be accomplished by a shoulder apparatus of leather and cloth with broad shoulder straps crossing in the back, so applied as to draw the shoulders backward and give the thorax proper opportunity for expansion.

V. CONGENITAL SYNOSTOSIS OF THE CERVICAL SPINE

1. Definition

This is a rare type of malformation of the cervical spine belonging to the group of developmental arrests. The first specimen of this kind was demonstrated by Hutchinson[62] in 1894, who found fusion of the vertebral bodies associated with a cleft of the 3rd, 4th, 5th, and 6th cervical arches.

From the earliest description of this deformity its nature remains in doubt as the anomaly is usually mentioned in connection with other congenital deformities, such as elevation of the scapula. In 1912 Klippel and Feil[74, 75] had occasion to examine a case of this kind roentgenologically as well as anatomically. It was a man of forty-six in whom the 7th cervical as well as the first four dorsal were entirely fused together producing a nondescript cervico-dorsal mass. Since then the condition has become known, especially among French authors, as the Klippel-Feil syndrome. Other observations soon followed. Bertolotti[12] in a very extensive treatise on congenital malformation of the cervical spine cites three observations. Other contributions were made by Dubreüil,[36] Chambardel, Ingelrans[63] and others.

2. Etiology and Pathogenesis

We are entirely in the dark as to the cause of this deformity. All that is known is that it has to do with a disturbance of the osteogenetic development of the medullary canal from the surrounding mesenchymatous tissue. It is essentially a failure of normal differentiation of the metameres or segments of the spine associated also by a disturbance of the muscle segmentation and a resulting muscle defect. The latter leads to formation of bony, cartilaginous or fibrous plates not normally provided for by the natural segmentation of the muscles (Putti[100]). Such fibrous strands are seen, for instance, also in congenital elevation of the scapula. Here the so-called articulations made of cartilage, fibrous tissue or bone, run from the median angle of the scapula to the spinous process of the 7th cervical. A definite point is made of this feature of disturbed segmentation of other than skeletal parts, because it again shows that the deformities are not to be regarded as isolated affairs concerning the skeletal spine alone. They develop too early in embryonal life not to involve also the metamerization of the muscle apparatus, or of other structures developing from the mesenchyme. So we must not be surprised to find associated with this condition other deformities, such as facial scoliosis, torticollis, congenital elevation of the scapula, fibrous transformation of the sternomastoid muscle, partial defects of the trapezius, pectoralis, etc. The time for this developmental arrest must fall into the period of the membranous preformed spine, that is, the first fetal month, since with the beginning of the cartilaginization the definite form of the spine becomes prearranged. This explains the frequent combination with other spinal anomalies of different types, such as the patency of the arches,

PLATE IX

Fig. 1.—Congenital scoliosis. Absence of ribs. Spina bifida occulta. Clubfeet. (See Fig. 4.)

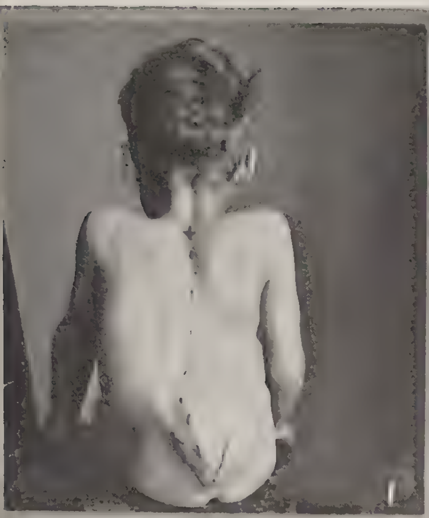
Fig. 2.—Congenital short neck. X-ray Fig. 5. Synostosis.

Fig. 3.—Congenital short neck. X-ray Fig. 6. Synostosis.

Fig. 4.—Absence of ribs. Congenital scoliosis. Spina bifida occulta. (Patient of Fig. 1.)

Fig. 5.—Congenital synostosis of cervical spine. (Patient of Fig. 2.)

Fig. 6.—Congenital synostosis of cervical and upper dorsal spine. (Patient of Fig. 3.)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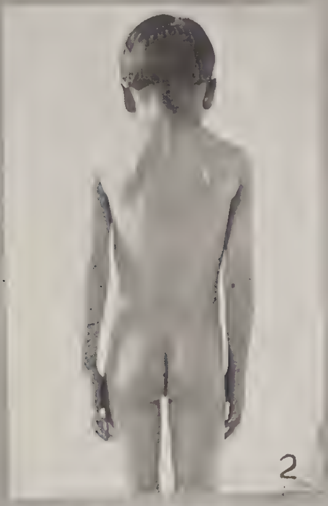
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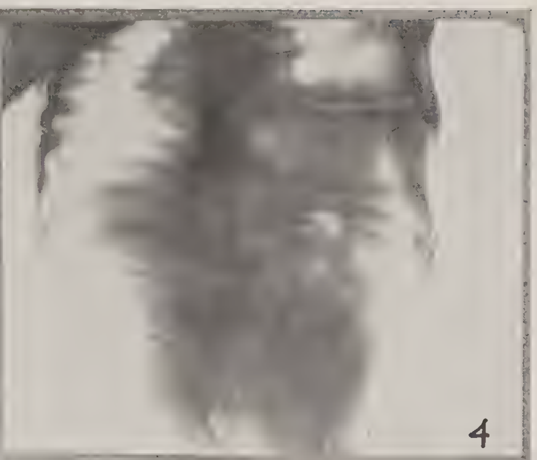
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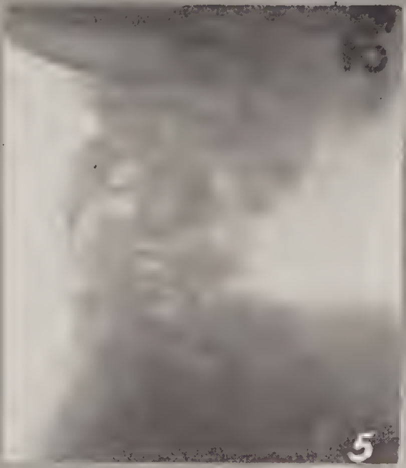
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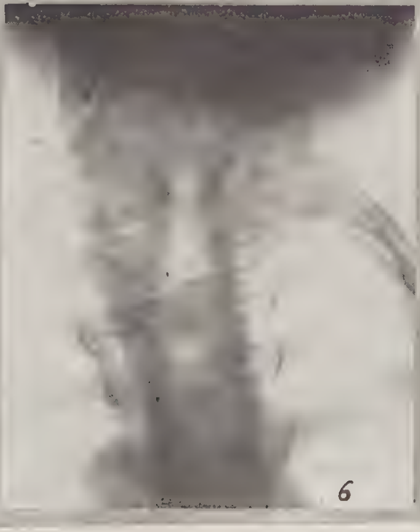
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PLATE IX

wedge formation, and fusion. All this points to the conception of Boehm[18] that these anomalies are part of one powerful agency, involving more or less the entire spine as well as its muscular apparatus. The condition is especially noticeable in the levels of transitions of the spinal sections, and we may classify it as a combination of numerical and morphologic anomalies of the spine.

3. Pathology (Plates VII, 3; IX, 5, 6)

The cardinal feature is the fusion of all, or at least of the lower cervical vertebrae, eventually also of the upper dorsal bodies into a homogeneous mass of bone. This mass of bone may, or may not show traces of segmentation. The posterior portion, however, that is the arches, are not developed and there exists a spina bifida cervicalis. Usually three or four lower cervicals are involved together with one, two or three of the dorsal vertebrae. Next to the spina bifida of the arches and the rudimentarily developed lower cervical and upper dorsal spine, we notice the crowding of the upper ribs, the frequent occurrence of a cervical rib on one side, and also a more or less pronounced asymmetry of the face. Changes in the position of the scapula have been observed, and cases of congenital elevation of the scapula with all attending features have been reported.

While the fusion most often involves the lower cervical and upper dorsal section, ankylosis between occiput and atlas has also been recorded, and is, according to Fischel,[42] not especially rare. Much rarer is the synostosis between atlas and odontoid. More frequent again is fusion between the 2nd and 3rd cervical vertebrae, or a synostosis of the lower vertebrae alone (Rokitansky).

4. X-ray Findings

The x-ray examination reveals the already described anomaly of the spine and the cleft of the vertebral arches. Differentiation of the upper dorsal vertebrae from the lower cervical is usually not possible. Wedge formation of one or the other vertebra can usually be made out. Schwahn[112] remarks upon the frequent concurrence of bilateral elevation of the scapula with fusion of the vertebral bodies (Plate IX, 5, 6).

5. Clinical Symptoms (Plate IX, 2, 3)

The most prominent symptom is the lack, or the abnormal shortness of the neck especially noticeable when looking at the patient from behind. The head seems to sit directly upon the thorax and shows a remarkable restriction of motion in all directions. Occasionally it assumes an oblique position resembling torticollis. The restricted movement of the head is, of course, due to the fusion of the cervical vertebrae and abolition of the vertebral articulations. This means that lateral motion and torsion are, if not entirely suppressed, at least very considerably restricted. Back and forward movement of the head is better preserved. One has the impression that all the movements are carried out by a single articulation, namely, the one joint between occiput and atlas, and that the gradual increase in the range of motion which is normally furnished by the lower cervical articulations is missing. One also notices the low border of the hair line which reaches way down in the neck and upper part of the back. To these principal signs Feil[74, 75] adds scoliosis or kyphoscoliosis in the upper cervical spine. Bertolotti[12] noted the lowering of the nipple line and the elevation of the shoulder, symptoms which bear evidence of the change in the relation between the scapulohumeral girdle and the thoracic cage. In a case of Schwahn[112] both shoulder blades were drawn high causing the arm to appear slightly inwardly rotated. Similar cases of Klippel-Feil syndromes are reported by Ingelrans, Mau,[88] and Meisenbach,[89] the latter describing a case of total absence of the cervical spine. The causes for the congenital elevation of the scapula and those for the fusion of the cervical spine run parallel, both being developmental arrests occurring early in life (Bibergeil[15]). Defects of the neuromuscular system are also found in combination with congenital fusion of the cervical vertebrae.

Cases are reported in which fusion of the upper cervical spine was associated with the malformation of the skull and with hereditary ataxia of the Marie type or Friedreich's ataxia (Bertlotti and Mattirolo[12]). In one case there was a numerical reduction of the entire cervical spine which showed only five complete elements and one-half vertebra with fusion of the atlas and occiput. In another case the lateral masses of the atlas were missing. In a case reported by Annovazzi[5] there existed a fusion of the posterior arch of the atlas with the occiput, and synostosis of all the remaining cervical vertebral bodies. Here also belong the cases of the so-called occipitalization (Putti[100]). In the case described by Klippel and Feil, of the twelve dorsal vertebrae, four were a nondescript fused mass, there being only twelve differentiated segments in the entire spine, namely, eight dorsal and four lumbar vertebrae, instead of twenty-four. The eight differentiated dorsal vertebrae carried one rib each on each side and the bony fused mass, four ribs on each side.

6. Treatment

No treatment is indicated, all attempts to increase motion by manipulation or otherwise are useless and harmful.

VI. CONGENITAL MALFORMATIONS AND DEFORMITIES OF THE THORAX

1. Absence of Ribs (Plate IX, 1, 4)

a. Classification.—A distinction should be made between the partial defects of ribs and sternum which are comparatively common, and the total defects of one or more ribs which are extremely rare. In the following it will be shown that neither of these two groups merits to be classed as an independent clinical syndrome since both total and partial absence of rib are invariably associated with other deformities of the skeleton. Lallemond[76] was the first to describe a condition of total rib defect, and up to 1913 there were only twenty cases collected in the literature by Hadda[54] to which he added three observations of his own. The largest collection is that of Putti, who observed absence of three ribs in two cases, absence of one rib in two cases, and in one case a total absence of four ribs. Of Hadda's cases one showed complete absence of two ribs and malformation of others with a cervical rib on one side and two on the other, wedged vertebral bodies, fusion, and defect of the anterior serratus muscle. In another case there was absence of one rib on one, and of two ribs on the other side, with fusion of rib and a cervicodorsal scoliosis. In the third, there was absence of one rib and a hemivertebra on the other side. Of the two cases reported by Joachimsthal[66] one showed complete absence of one rib with fusion of others and association with a cervical rib.

Most cases are brought to attention by concomitant deformities among which scoliosis and elevation of the scapula are the most frequent.

b. Pathogenesis.—The concomitant deformities of the spine seen in cases of total rib defects, such as wedge vertebrae, fusions, etc., must not be considered as secondary, but as the effect of a common deforming cause. This can be assumed from the ontogenetic relation between rib and vertebra. The rib is present even though one-half of the vertebral body or a portion of the arch be absent. But a rib is always found missing if there is no transverse process. Putti concludes that in the malformation of the thorax the rib is always and inseparably dependent upon the vertebral anomaly; absence of the costal element or its malformation or fusion always finds a corollary in errors of segmentation or differentiation of the spine.

c. Pathology.—Concomitant malformations of spine and thorax have already been mentioned. The most frequent are cleft of vertebral body, wedge formation of the vertebrae, suppression of the vertebrae, interpolation of vertebrae, cervical rib, and bony bridges. Others occasionally mentioned are congenital deformities of the breast with multiple nipples, and congenital defects of the upper extremity as a whole. The absence of one or more ribs creates a wide hole in the thorax which is filled by a membrane lying apparently directly under the skin. It bulges out under strain and pressure (Kienbock[71]); nevertheless, pulmonary herniation is very seldom observed (Riether[104]).

2. Congenital Muscle Defects. (Plate V, 3)

Only in three of the twenty-three cases of total rib defects reported were there found anomalies of the muscles. This, however, is probably due more to a lack of observation, no attention having been paid by the observers to the state of muscles. One rather sees in all cases of congenital elevation of the scapula which are combined with rib defects that muscle anomalies are present. Lieberknecht[81] found the pectoralis major and minor poorly developed. Graetzer[50] observed a defect of the lower third of the trapezius, besides weakness of the serratus anticus and atrophy of the upper portion of the long muscles of the back. The congenital defect of the pectoralis muscles is not an uncommon observation. It was first described by Ziemsen in 1857, who estimated that it constituted 0.4 per cent of all malformations of the trunk, and Bing, in 1902 was able to collect six hundred cases in the literature, most of them associated with congenital elevation of the scapula. It would, therefore, appear that many cases of congenital defects of the rib are associated with this pectoralis defect, though more accurate data on this, as well as on other concomitant deformities, are needed. Further observations of congenital defect of the pectoralis muscle in a case of total absence of ribs, and in other cases combined with scoliosis are reported by Tedeschi.[119] Other reports of congenital absence of ribs include defects of the pectoralis minor and the serratus anticus as well. A double, almost complete absence of the trapezius muscle is described by Erb (1889), in this case, however, it was undecided whether a congenital deformity existed or a later developing pathologic process, possibly a progressive muscular dystrophy. Voltz[125] describes congenital absence of the trapezius in a sixteen-year-old boy which became noticeable after heavy lifting.

3. The Congenital Funnel Chest (Pectus Infundibulatum. Plate XIV)

a. Pathogenesis.—The majority of observers are of the opinion that the deformity is occasioned either by some disturbance of fetal development, or by a mechanical factor. The mechanical theory, however, is losing ground, (Bien[16]) because of concomitant congenital anomalies of the thorax which indicate more intrinsic causes in form of developmental arrests (Walther[128]). Furthermore, the frequent occurrence of more or less pronounced degenerative stigmata and of nervous and psychic symptoms in the family also point to some familial and hereditary factor. In this deformity the effect of the respiratory mechanism is probably only contributory. The retraction of the lower end of the sternum is facilitated by the softness and pliability of the ribs and also by the relaxation of the abdominal muscles. This is to be regarded as a secondary constitutional factor which produces a mechanical effect upon the thorax quite similar to that seen in rickets, in which deformity, also, the relaxation of the abdominal wall, and the pliability of the ribs, permit a retraction of the lower end of the sternum by the contracting diaphragm. In the case of congenital funnel chest another factor must be added to the causative agency; namely, the obstruction of the upper air passages, enlarged tonsils, hypertrophied adenoids.

The mechanistic theory seems to receive some support by the combination of the funnel chest deformity with micrognathia (Kaumheimer[68]). This latter deformity occurs most frequently in combination, for instance: malformations of fingers and extremities, harelip, cleft palate, etc., and is explained by the mechanical effect of strong flexion of the head and subsequent pressure upon the mandible. Kaumheimer believes that the great majority of cases of either micrognathia or funnel chest must be explained by endogenous or intrinsic forces, but, that for the combination of the two deformities, the mechanical factor of hyperflexion of the head against the thorax must be considered.

b. Pathology.—The salient pathologic feature is the depression of the sternum; it forms a more or less deep furrow or groove and the thorax appears flattened in front, the infrasternal angle is small. The deepest portion of the groove lies at the junction between the body and the ensiform process. Displacement of the organs contained in the thoracic cage has been observed, especially of the heart which was found shifted as a whole to the left and rotated about its sagittal and longitudinal axis.

c. Clinical Symptoms.—In lesser degrees of the deformity there is merely a depression of the body of the sternum, while in more advanced degrees the whole sternum appears depressed, including the manubrium. The anteroposterior diameter of the chest is decreased, the sternum is impeded in its upward, as well as its forward movement during inspiration. The respiratory excursion of the thorax appears diminished, and the whole thoracic cage assumes more of an expiratory position manifested by the more slanting direction of the ribs. The posture is decidedly asthenic; the abdominal respiration prevails. The muscles of the anterior abdominal wall are relaxed, the thorax is held backward, the abdomen protrudes, the patient showing malposture of a flat or round hollow back type. (Plate XIV, 4, 5.)

d. Treatment.—First consideration should be given to the condition of the upper air passages. Tonsils and adenoids if enlarged or hypertrophic should be removed.

The local treatment is directed principally toward the developing of the muscles of the chest and the correction of posture. Systematic development of the thoracic muscles, especially the pectorales, serratus and trapezius, by setting-up exercises, club swinging, chest weights, practice, etc., is of great importance. The usual exercises for correct posture should be taught carefully. Deep breathing exercises are of great value in the development of the respiratory excursion. Finally, hygienic measures of general type must be instituted; the patients must lead a free out-door life, must be interested in athletic activities and sports to the extent of their physical ability and must be brought up on good and wholesome food.

The operative elevation of the depressed sternum, as sometimes suggested, is a hopeless and unnecessary procedure.

VII. COMMENT ON CHAPTER I: CONGENITAL DEFORMITIES OF SPINE AND THORAX

Investigations and studies of the subject of congenital malformations of the spine, undertaken in recent years, have greatly advanced our knowledge and understanding of the subject. They have brought out the all-important fact that such malformations are not isolated and incoherent phenomena, but that most of them are determined in a thoroughly coherent and systematic manner by powerful events of early developmental nature. Far from being haphazard and fortuitous occurrences, these deformities represent in all their diversities manifestations of a common cause. Many of the hitherto unexplained peripheral deformities, such as clubfeet, clawfeet, paralytic deformities, bladder deficiency, etc., can be brought into causal relation with congenital deformities of the spine, notwithstanding the tardiness of their appearance and the progressiveness of their course. Nor is this all. The recent investigations into this field, taking the normal and physiologic development as a starting point in the quest for knowledge of the pathologic processes have led us to recognize the physiologically abnormal conditions as transitional stages from which the pathologically abnormal conditions of the spine develop. By deepening the knowledge of the physiologically abnormal condition, it seems that perhaps the greatest advantage has been derived from these studies of congenital malformations of the spine. The conditions described in this chapter are only those that are of sufficient degree and force to produce pathologic manifestations, and they, in themselves, represent an important and interesting group. Behind them, however, different only in degree, is the much larger and more impressive procession of the innumerable physiologic variations. These conditions are not of sufficient force to produce pathologic manifestations, but they are most instrumental in predisposing the spine to such manifestations, they are, therefore, a potential pathologic factor. It is *this* element of physiologic variations, which essentially constitutes what we shall describe in later chapters as inherent weakness and lack of resistance of the spine, and we shall find them to be of the greatest influence in the static and traumatic disabilities.

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CHAPTER II

THE STATIC AND STATIC CONSTITUTIONAL ANTEROPOSTERIOR DEFORMITIES OF THE SPINE

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V. Comment on Chapter II

I. INTRODUCTION: GENERAL CONSIDERATION OF POSTURE. DEFINITIONS

It seems obvious that before designating a posture as good or bad, and giving reasons for one or the other, one must start with a definition of the term. Without reference to physiologic correctness we may first define posture of the body as the expression of its equilibrium and balance; in contrast, locomotion expresses a rhythmic play between loss of balance and its recovery. In posture the individual is at rest and its balance for the moment secured, in locomotion the balance is overthrown by the moving body, which, however, is constantly engaged in attempts to reinstate it.

Our normal posture is the end-result of a long continued process of adaptation from a quadrupedal, or some other earlier form of balance, to the bipedalistic balance of man. In evolution, posture has kept step with the developmental current of the body as a whole, so it must be regarded to be in the same state of flux of genetic development which applies to the body. To consider posture as a thoroughly stable, anatomically unchangeable fact would be to misinterpret and to misunderstand its evolutionary character. We are stressing this point merely to show that posture as a physiologic state must be given some latitude; instead of speaking of normal posture as a fixed or rigid condition, it is better to speak of a physiologic range of posture, that is, the field of individual variation within which posture may swing back and forth and yet be within the normal physiologic limits.

Our next concern is to determine this range within which posture can be designated as normal. To do this, we select one definite line or point within the human body to which the human spine, in an upright position, bears a certain anatomic relation. We may then designate as physiologic posture, the range within which the human spine still bears the same relation to the chosen line or point of the body.

1. Relation to Line and Center of Gravity

From the kinetic and dynamic point of view, it must be the line and center of gravity of the human body which are chosen as the constant values. We then make normalcy of posture for any individual spine, contingent upon whether or not this spine satisfies the requirement of definite anatomic relations to line and center of gravity. If we find this relation to be within certain normal limits, we speak of normal posture.

It now remains to state what these normal relations of the body and the spine are, as to line and center of gravity.

a. We find that in animals the weight center of the body varies greatly according to the difference in build and in postural habits. In the dog, head extended, the weight center of the body is brought closer to the forefeet, being situated in a line close behind the shoulder blades. Trained to rear upon his hind legs, his weight center remains high above the pelvis, and it must be studiously kept over the small area of support, represented by the paws of his hind legs. Hence the great difficulty in performing this trick which creates an extremely labile body balance. Squatting on his haunches is easy for him because the weight center becomes lower and the supporting surface is greater.

In certain animals, the bison, the camel, for instance, the weight center is still farther in front, so that the forelegs sustain a greater portion of the body weight. In some of the great prehistoric reptiles we see the center of gravity move backward, as in the brontosaurus; so it is also in the kangaroo and other herbivorous animals, which, feeding from the trees, are compelled to raise their bodies and to balance themselves on hind legs and heavy tail. As we consider the animals which represent the erect cursory biped mode of locomotion, one that is well comparable to that of man, we see that the anthropoid apes do not possess a tail which might be used for counterbalancing purposes, but all of them have the thighs extended up on the body to a degree not observed in the lower forms of mammals. In the resting position these animals usually use their forelegs, while in motion they frequently adopt a semierect or erect position. By force of circumstances there came later into the mode of locomotion the so-called principles of brachialism, meaning the use of the upper extremities, as the inevitable result of the so-called arboreal habits of the apes. Several of these took well to the change from bipedalism to arboreal habits, others, like the gorilla, have been forced to give up living in trees largely because of the enormous body weight. With these arboreal habits an increased development of the upper extremities of the body resulted, and the center of body weight again moved up.

b. When, later, erect walking was assumed, as it was in man, we find that the bipedalism, owing to the higher weight center, again entailed a more difficult function. With the higher development of the muscles of the thorax and of the upper extremities, and the relative retardation in the development of hip and legs, it is not surprising that some of the larger apes, after a period of arboreal habits, fell again, secondarily, into a state of quadrupedalism. We must consider that erect posture in man developed not directly from a terrestial pronograde posture, but by interposition of a so-called long-arm state acquired during the arboreal period. So it appears that the direct bipedalism is founded upon a new relation of the hip, of the thigh, and of the pelvis; the structures about the hip joint having become gradually modified for the erect posture.

For the understanding of the phylogenetic development of the upper extremity and thorax, as well as of their relation to the lower extremities and the pelvis, these considerations are of great importance.

Coming back to man's erect posture of which we said, that it developed under the influence and after a long period of arboreal habits, we find, therefore, the obstacles to his upright standing further increased by the mighty development of his arms and upper trunk. The key to the solution of the problem obviously lay in the development of the extensors of the hip, the extensors of the back, and the proper angle of inclination of the pelvis. It was these three points that principally determined his ability of walking and standing upright, and about which the problem of his posture centered. In more current terms we may say, that three points determine posture, namely, the development of the extensors of the hip, of the extensors of the back, and of the inclination of the pelvis. Accordingly we find in the further phylogenetic development, as guarantee of erect posture, a great preponderance of the hip extensors over the flexors, and the great development of the musculature of the back; the first two prerequisites of erect posture. The center of gravity we see not only move downward again with the greater development of the limbs, but also backward, closer to the spine, and in this arrangement the inclination of the pelvis plays an important rôle. This is the third prerequisite of erect posture.

The normal inclination of the pelvis is about 50 degrees to the horizontal plane when the body is in upright standing position; an increased inclination of the pelvis involves an increase in the lumbar lordosis.

2. Line and Center of Gravity in Static and Dynamic Functions of the Upright Body

The effect of shifting of the center of gravity incident to the changed inclination of the pelvis and to the erection of the spine, is that the line of gravity now keeps close to the spinal column. It intersects with the physiologic anteroposterior curves of the spine at certain definite levels. If we construct this line upward on the supporting trapeze formed by the feet it goes in front of the astragalus, passes upward and immediately in front of the knee joint axis, falls slightly behind the center of the hip joint, between it and the common sacroiliac axis, and then intersects the spine, first at the lumbodorsal junction, then, crossing in front of the dorsal spine, at the cervicodorsal junction and then runs upward back of the cervical spine touching the skull at the mastoid process (Plate X, 1). Under this condition we speak of a normal distribution of the gravital forces. The weight bearing center of the body is situated just in front of the 4th lumbar vertebra. Even if a considerable degree of lordosis exists in the lumbar spine it may be compensated by a correspondingly higher degree of kyphosis of the dorsal section so that the center of gravity still remains in the same position, it being shifted neither backward nor forward, and the line of gravity still intersects with the spinal column at the usual levels.

Again, upon the erect position of the trunk and its relation to the line of gravity depends the functions of the thoracic cage and the function of the abdominal wall. No essential departure from the normal posture is possible without impairment of the function of the respiratory mechanism as well as of the abdominal balance. In malposture the forward flexion of the dorsal spine embarrasses the respiratory excursion of the ribs; it causes the ribs to slant and places them in a more expiratory position so that the vital capacity of the thorax appears diminished. The abdominal balance on the other hand, depends not only upon the anatomic condition of the intraabdominal organs, but very largely also upon the physiologic tone of the abdominal wall, the latter being the most important means of maintaining normal, physiologic intraabdominal pressure. Consequently, as we see the body in malposture change its normal relation to the line of gravity, we immediately note the effect of it upon the anterior abdominal muscles expressed by the protrusion of the abdominal wall, the relaxation of the muscles and the swayback condition of the lumbar spine.

II. PATHOLOGIC POSTURE

1. Relation to Line of Gravity

From the static point of view we may distinguish the following types of posture in which the line and center of gravity, more or less, vary from the normal relation with the spine.

a. In the first group the weight line falls between hip and common sacroiliac articulation, but there is a more than the normal inclination of the pelvis. This results in increased lumbar lordosis, compensated by adequate kyphosis of the dorsal spine: the round hollow back; or, conversely, the inclination of the pelvis is less than normal, and both lumbar and dorsal curves are correspondingly flatter: the flat back. These cases are well and securely balanced and because the relation of the spine to the line and center of gravity is not materially changed, it may still be considered physiologic.

b. In a second type the weight-bearing center is displaced forward. As the hips are held in flexion the whole trunk follows forward, the knees are flexed, the line of gravity strikes the anterior portion of the supporting area. This posture we find in certain inflammatory and other pathologic conditions. Here the center of gravity is shifted to a plane in front of the hip joint, consequently the line of gravity is also displaced forward, the balance of the forward flexed trunk can only be maintained by a corresponding flexion position of the hip and this again necessitates flexion in the knee

PLATE X

Fig. 1.—Relation of line and center of gravity to body. (After Fick.)

Fig. 2.—(A) Tall, slender anatomic type.
(B) Short, heavy anatomic type.

Fig. 3.—(A) Tall, slender anatomic type.
(B) Normal anatomic type.

Fig. 4.—Short anatomic type. Note wide costal angle.

Fig. 5.—Round upper back in normal anatomic type.

Fig. 6.—Round back in slender anatomic type.

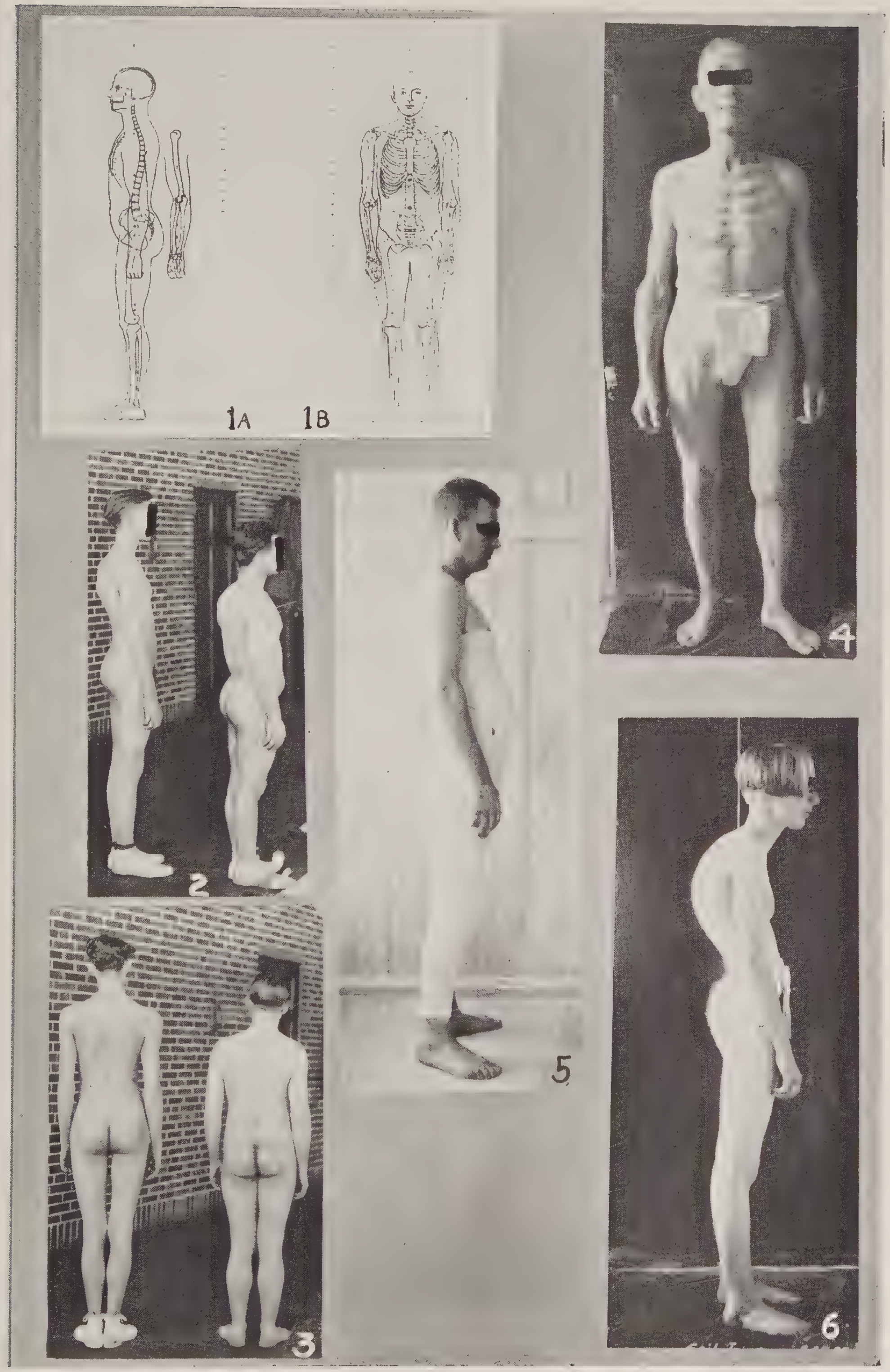


PLATE X

joint. The inclinatory angle of the pelvis becomes greater than normal. A strain is thrown upon the long muscles of the back, the function of which is to hold the upper portion of the body backward.

c. More commonly we find the line of gravity to move backward so that it falls into the sacroiliac articulation or even behind it. This is a frequent occurrence in pathologic posture; we find it in infantile paralysis where the muscles of the abdominal wall are weak or in pseudohypertrophic muscular dystrophy and other paralytic conditions. It is found as purely static malposture in the flat or round types of back, when the body balance which is normal for the respective type, is overthrown. The backward throwing of the body may occur either in the hip joint with the inclination angle of the pelvis remaining the same or being diminished, or, in the lumbar spine, by increasing the lumbar lordosis, in which case the angle of inclination of the pelvis also increases. We may see then, in the different configurations of the spine, mere physiologic variations, as long as they remain in typical relation to line and center of gravity. Great individual variation of the human spine is being generally recognized since Parow's[20] classical measurements. Yet some of these, still physiologic, spines must be less stable in their equilibrium (flat back) than others (normal and round hollow).

2. Clinical Types of Malposture

From the clinical viewpoint we shall first consider the transgression from the physiologic to pathologic attitude as a whole: Malposture; and secondly, its effect upon the respiratory, circulatory, and digestive function in particular: Viceroptosis.

(a) *Clinical Pathology of Faulty Posture.*—Malposture of the body should be considered and described as it develops from the different physiologic types of posture. It is obvious to the most casual observer that in the anatomic construction of the spine there are innumerable individual variations. According to Goldthwaite,[11, 12] whose work on posture is of the most fundamental importance, the following three physiologic types may be distinguished: (1) a normal type with full or moderately rounded thorax, a high diaphragm. The lower abdomen is flat, the upper rounded. The patient carries himself with the shoulders drawn back, the thorax in an inspiratory position, most favorably balanced to display the best degree of respiratory function (Plate X, Fig. 3-*B*); (2) the narrow back type, or carnivorous type (the slender anatomic type of Willis[27]), here the build of the body is light, the individual is tall, slender, delicate, with a large head, high palate, often with hypertrophic tonsillar and adenoid tissues. He also has a long, narrow chest, a small costal angle, and a long body, especially in the lumbar region. His ribs are slanting, the individual vertebral bodies appear slender, high and the flexibility of the lumbar spine in all directions is especially great (Plate X, Fig. 2-*A*, 3-*A*); (3) the broad back, herbivorous type (the heavy anatomic type of Willis). In contrast to the former the body in this type is built upon heavy lines. The skeleton is large, heavy in structure, there is an excess of fat throughout the body, the head is round, the face broad, the neck short. The chest is large, the costal angle is wide, the diaphragm stands high, the lumbar region is short, and the abdominal cavity is broad and deep (Plate X, Fig. 2-*B*, 4). The spine is broad and heavy, the vertebrae are more flat and show stronger articular processes. Often there is an iliotransverse articulation as a long 5th lumbar transverse process is set deep between the flares of the os ilei, articulating with the latter. The sacrum occupies a more perpendicular position so that the inclinatory angle of the pelvis is diminished, in contrast to the slender type or long narrow backed individual in whom the sacrum occupies a more horizontal position, and in whom the angle of inclination of the pelvis is correspondingly greater. In this heavy type the mobility of the lumbar spine is restricted, there is a disposition to sacrolumbar strain in contrast to the slender type in which the strain is exaggerated in the sacroiliac articulation, and the individual is more disposed to disturbances in this latter articulation. It cannot properly be said that certain forms of malposture correspond to certain anatomic types, but when control of normal body balance is lost, there are definite postural anomalies prevailing in one anatomic type and others in another. The clinical types of malposture are, according to Lovett,[16] the round upper back, the round back, the round hollow back, and the flat back. With this correlationship in view one may formulate a clinical classification of postural deformities as follows:

(1) From the Normal Type.—

(a) *The Round Upper Back (Lovett).*—In correct position, hips, shoulders, chest, spine and pelvis are well balanced and perfectly aligned over the supporting surface, giving the greatest possible freedom of motion and the greatest ease of function. In the relaxed position the shoulders drag forward and downward, and the pelvis changes its inclinatory angle, which, in this type of malposture, becomes lessened. The position of the chest is lowered and becomes more expiratory. The diaphragm is depressed and the abdominal wall is relaxed and protruding. The center of gravity is thrown backward at the lumbar level and this is compensated by a forward flexion of the upper portion of the trunk. The inclinatory angle of the pelvis appears lessened by hyperextension in the hip joints (Plate X, 5).

(b) *Round Hollow Back.*—A round hollow back may likewise develop from the normal type. The body balance overthrown by the backward movement of the upper trunk, is recovered by a compensatory lumbar lordosis, although not in sufficient degree to make up for the backward displacement of the center of gravity (Plate XI, 1).

(2) Slender Anatomic Type.—The carnivorous, narrow back (slender anatomic type) develops the following malpostures:

(a) *The Flat Back.*—The whole body is carried backward by hyperextension in the lumbar region, making a sharp curve at the lumbosacral level. The body

PLATE XI

Fig. 1.—Round hollow back. Normal anatomic type.

Fig. 2.—Flat back. Slender anatomic type.

Fig. 3.—X-ray of Fig. 2. Normal epiphyses.

Fig. 4.—Visceroptosis. Postinfantile paralysis.

Fig. 5.—Visceroptosis. Postinfantile paralysis.

Fig. 6.—Visceroptosis in faulty posture.

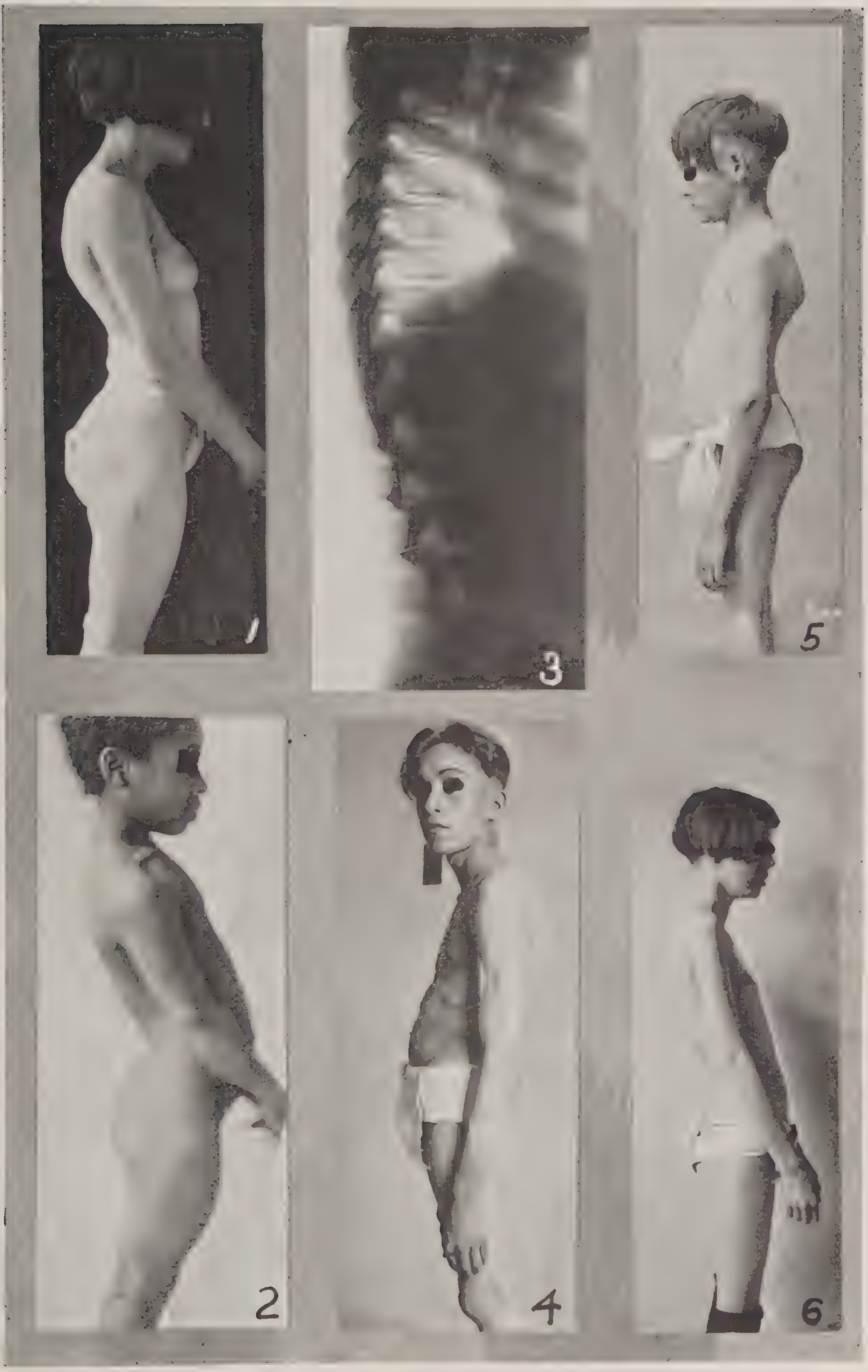


PLATE XI

appears erect due to the low lumbar lordosis, and the extension added in the middorsal region. The upper part of the abdomen, however, is carried backward and the pelvis is tipped forward and downward so that its inclinatory angle is increased (Plate XI, 2, 3).

(b) *The Round Back.*—In this malposture the body as a whole is likewise carried backward, but there is a compensatory forward flexion of the upper portion of the trunk which causes the entire spine to curve backward. In this type the inclinatory angle of the pelvis is increased sometimes as much as 30 to 40 degrees, and it is this malposture which predisposes to strain of both sacroiliac and sacrolumbar regions (Plate X, 6).

(3) The Broad Back, Herbivorous, Heavy Anatomic Type.—

(a) The most common type of malposture is the round hollow back. It shows a backward inclination of the body as the weight of the abdomen increases. Because of the perpendicular position of the sacrum, however, this backward movement of the trunk is not accomplished by the sharp kinking of the sacrolumbar junction as is the case in the round back or the flat back of the slender anatomic type, but the whole of the lumbar spine is engaged in a compensatory lordosis. As in the normal anatomic group this compensation may not be sufficient to recover the normal relation of the body to the center of gravity.

(b) The round hollow back likewise occurs in the heavy set individual as a malposture in which the body as a whole, is being carried backward, compensated by forward flexion of the upper portion of the trunk, without, however, developing an adequate compensatory lumbar lordosis.

It is obvious that of the three types of anatomic construction, the slender anatomic type is the least stable, and therefore, the most liable to develop attitudes of malposture.

3. The Treatment

Its objective is to restore the body to the normal relation with line and center of gravity which existed in the particular anatomic type, while body balance was still under full control. In the round upper back, in the round back, the loss of muscle control may, in course of time, lead to structural changes which offer great difficulties to the correction of the deformity.

a. Muscle Development and Mobilization.—As in structural scoliosis the first step of the treatment should be the mobilization of the parts, but unlike the latter condition, the musculature of the back after regaining its normal tone and strength is much better able to maintain the balance than it is in the lateral deformities of the spine. Therefore, the relaxation of the structures need not be feared as much as in the correction of scoliosis (see Chapter III). Lovett maintains that the stretching of the soft parts by gymnastic exercises is a slow and often unsatisfactory procedure and advocates passive stretching, either manual or by means of apparatus. In severer cases a plaster of Paris jacket may be applied in improved position. These jackets are worn from two to four weeks, changed, if necessary, and are ultimately supplemented by braces or corsets which should be worn long enough to allow the musculature to regain its normal tone and strength (Plate XII, Fig. 3, 5). The principle of the treatment is the systematic development of the long muscles of the back, and of the muscles of the shoulder girdle. For this purpose a number of suitable exercises have been devised. Lovett divides these exercises into those applied in standing, and those in horizontal position. In all exercises in standing position the pelvis should be fixed. In this position, most important are trunk stretching, trunk bending, and trunk twisting exercises. In all of these the patient stands erect, hands on hips, to assume the best possible position of self-correction (Plate XII, 1, 2, 4, 6).

Exercises carried out in recumbent position are given with the patient either prone or supine. Trunk raising and trunk bending exercises with concomitant respiratory movement are of great value. Lying on his face the patient has his trunk supported on a table or hanging free over it (Plate XIII, 1). Lying on his back, the patient carries out sitting exercises by rising to sitting position with both arms folded over the chest, as well as lateral bending and twisting exercises. At the same time the development of the abdominal muscles, as part requirement for the regaining of normal postures, should not be neglected (Plate XII, 1). To improve the carriage, the carrying of weight upon the head, and other balancing exercises are very useful. To check up on the self-corrective effect of these exercises, mirrors supplied with plumb lines are very practicable.

b. Contentive Braces.—Braces and corsets are to secure and to retain the improvement gained by the methods of muscle development. They are not intended as permanent appliances. According to Lovett the use of supports to maintain the spine in correct position is indicated in children with lax muscles, unable to hold their position between the muscle treatments; after forcible correction, as well as in resistant cases which are being stretched but likewise cannot maintain the improvement between stretchings (Plate XII, 3, 5).

A simple brace answering the purpose consists of a horizontal pelvic band which encircles the posterior part of the pelvis from one anterior superior spine to the other and carries uprights running along the side of the spine as high as the acromion process. At this point the uprights curve out on the flat and take an angular turn to run over the shoulders. From the upper end of the upright, shoulder straps run in front under the arm pits to the back, crossing there, and then returning to the front are fastened to the anterior ends of the base band (Plate XII, 3).

In the convalescent stage, the braces may be displaced by corsets made of strong webbing and reinforced by steel stays which must be constructed high enough to give adequate support to the shoulder girdle (Plate XII, 5).

PLATE XII

Fig. 1.—Postural exercises. Development of abdominal muscles.

Fig. 2.—Postural exercise. Development of thoracic and pectoral muscles.

Fig. 3.—Retentive apparatus: braces.

Fig. 4.—Postural exercise.

Fig. 5.—Retentive apparatus: corset.

Fig. 6.—Postural exercise.

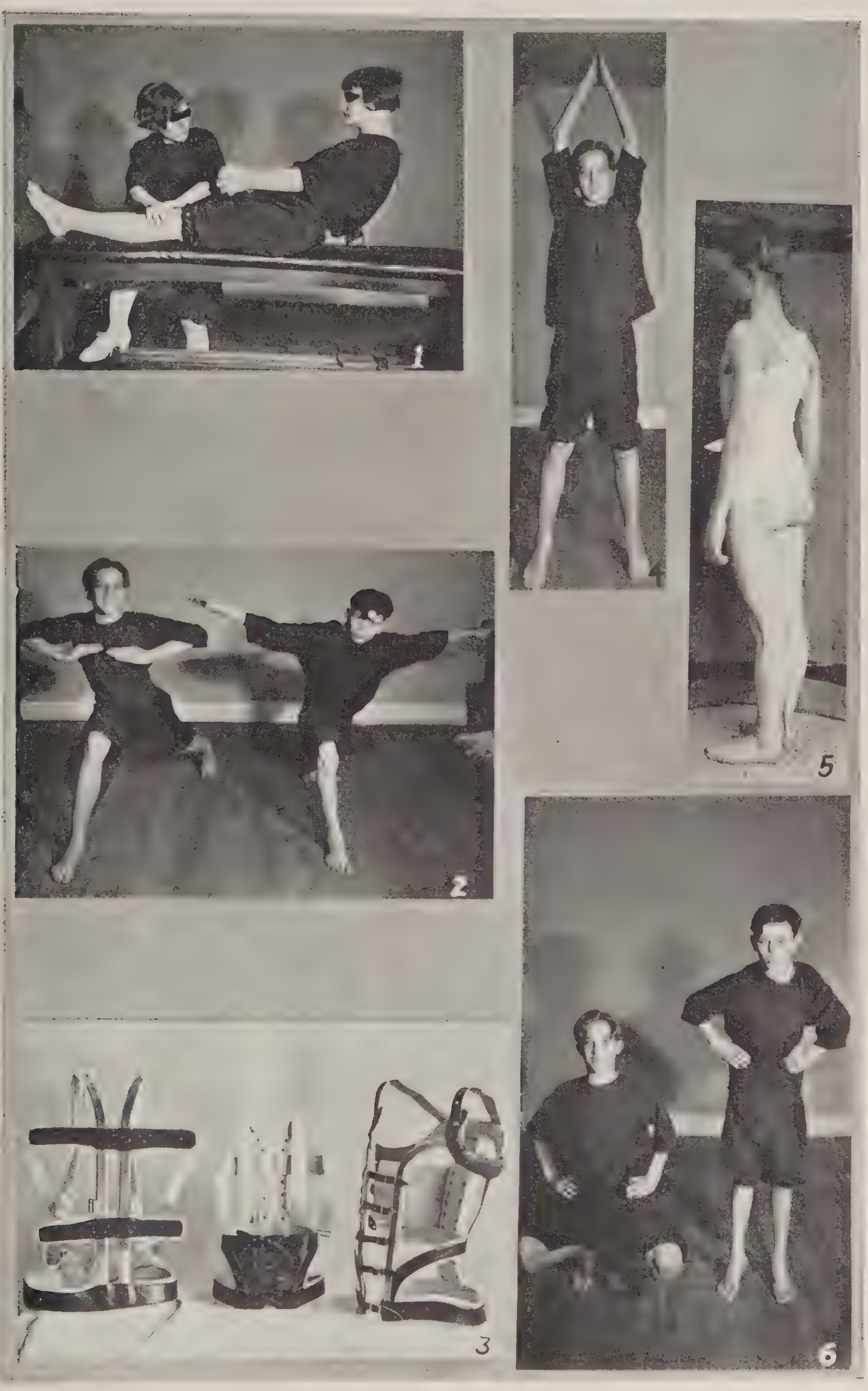


PLATE XII

III. VISCEROPTOSIS

1. General Remarks

It was stated in the previous section that visceroptosis or enteroptosis is mechanically inconceivable without concomitant changes in the posture of the patient, because of the intimate interdependence of the respiratory and abdominal systems with the position of the spine.

As we have defined the state of health of the body from the mechanical point of view, as a condition in which all positions are perfectly balanced against intrinsic and extrinsic physical forces, so also we may, by contrast, define visceroptosis as a condition in which the body, and particularly the organs of the great body cavities, are forced to yield to gravital and other physical laws. Against these the body is no longer able to set up the normal resistance that exists in perfect body balance. As the result of it, the relations between the visceral organs and the body are altered.

In the previous paragraph we were concerned with the relation of the spine to the line and center of gravity. In order to appreciate the departure from the normal we first had to establish the relations in space between line and center of gravity and spinal column, by marking the points of intersection between line of gravity and spine. In this normal relation we recognized the condition in which the body is most advantageously balanced against both forward flexion and backward extension.

What, then, is the normal dynamic balance of the respiratory apparatus and the abdomen?

First of all, it must be remembered that both the respiratory and the abdominal systems depend for their function upon the erect posture of the spine to which they are anchored, so to speak. Each of these systems has its own intrinsic balance.

a. The Intrathoracic Balance.—The thoracic respiration represents the play of the ribs in an up- and downward movement against the spine. There is a point of equilibrium between the respiratory forces which is situated somewhere within the inspiratory phase of respiration. We may say, then, that the normal thorax when at rest, is in a position of slight inspiration. To produce further inspiration we must increase the volume capacity of the thoracic cavity. This is done by the elevation of the ribs and the descent of the diaphragm. Both forces act in unison; elevation of the ribs and contracture of the diaphragm occur at the same time. As the ribs are elevated to increase the capacity of the thorax, a certain amount of resistance, which is represented by gravital and other stresses within the thorax, must be overcome. Likewise, as the diaphragm contracts in inspiration to contribute its share in the enlargement of the thoracic cavity, it does so also against a definite resistance. This latter resistance is represented by the contents and the muscular wall of the abdominal cavity. The muscular wall particularly, in resisting the change in form of the abdominal cavity which the descending diaphragm tries to exact, increases, by its contraction, the interabdominal pressure.

b. Abdominal Balance.—Between thorax and abdomen such an arrangement is absolutely necessary for the normal play of respiration; without it no satisfactory expiratory return could be made to the inspiratory movement of the diaphragm. The inspiratory movement would be more shallow because without the abdominal pressure the intrapulmonic pressure would be lower, and the ribs which are elevated in inspiration could not be drawn up as high as they are under normal conditions.

The expiratory movement of the thorax would be even more impaired by the absence of the abdominal pressure, since it is largely the contraction of the abdominal muscles which forces the diaphragm upward into a strong expiratory position. So we have two factors in the respiratory movement: a thoracic factor which causes the ribs to rise and fall, and an abdominal factor which causes the diaphragm to descend in inspiration and rise in expiration, thereby increasing, or decreasing periodically the capacity of the thorax. Now we know that the obdominal cavity is composed of soft tissues and organs and liquids, and only to a very small amount, of gaseous contents, and, therefore, is subject to hydrostatic laws. In other words, the abdominal cavity practically does not change its volume, but it constantly changes its form. So, as the diaphragm descends the abdominal wall bulges out, and herein lies the keystone for the mútual play between diaphragmatic and abdominal muscle action.

There is considerable amount of stress active upon the abdominal wall. Not only must it resist the alternating interabdominal pressure transmitted to it by the diaphragm, but it is also exposed to the weight of the interabdominal organs of which it has to bear a greater part. As long as the abdominal wall is intact, that is, as long as it can display the necessary degree of tension to resist the weight stresses of the abdominal organs, and the tension stresses of abdominal pressure, the balance is maintained. But when, for one reason or another, the abdominal wall loses its tension strength and becomes relaxed, then the diaphragm descends to a lower point, that is, it maintains a lower respiratory level than normal. The abdominal pressure now is not strong enough to force it upward into the normal expiratory position. The abdominal wall also sags under the weight of the abdominal organs, especially in its lower portion where the gravital stresses are the greatest.

c. Interrelation between Posture, Thoracic and Abdominal Balance.—The relation between the three principal mechanical systems which maintain the balance of the body; namely, the posture of the spinal column and pelvis, the respiratory balance and balance of the intraabdominal pressure can then be analyzed as follows: The trunk is stabilized in what is considered an advantageous posture with regard to line and center of gravity of the body. The thorax is balanced so that all its forces acting upon it, whether intrinsic or extrinsic, find a neutral point of equilibrium in a position which is that of inspiration. The inspiratory position of the thoracic balance again imparts through the elevated ribs a certain degree of tension upon the abdominal muscles, and, thereby, indirectly helps the anterior abdominal wall to bear some of the weight of the intraabdominal organs. The third system is represented by the abdominal walls and their contents. The contracture of the diaphragm and the contracture of the abdominal muscles conjointly or singly, alternating or simultaneously, increase interabdominal pressure even though they do not change the volume capacity of this cavity. The three mechanical systems, namely, trunk, thorax, and abdomen, are, therefore, closely interrelated in their function and for all three there exists what might be considered a normal physiologic state of balance. Should one of these systems fail in this balance, it necessarily endangers also, the balance of the other two. It is for this reason that we find it opportune to consider imbalance of the body as a whole, before discussing the imbalance of the abdominal cavity. We see then that faulty posture has an immediate effect upon the function of the thorax as well as upon the function of the abdominal wall and the intraabdominal organs.

2. Pathology of Visceroptosis

The principal feature of visceroptosis is the sagging of the abdominal wall and the relaxation of its contents. It now becomes of interest to consider the normal provisions which are made to meet the weight-bearing stresses of the intraabdominal organs, and the strain of the intraabdominal pressure.

How do these provisions fail?

a. Psoas Shelf.—Part of the weight of the intraabdominal organs is carried by what is called the psoas shelf, that is, a shelf formed by the lordotic lumbar spine and the psoas muscle. The attachment of the hepatic and splenic flexures of the colon is external to the kidneys and to the posterior surface of the abdominal cavity. Fully two-thirds of the right lobe of the liver are behind what is called the perpendicular psoas line, that is, the perpendicular line touching the anterior edges of the psoas outlet. Therefore, all organs above and back of this line are carried largely by the prominence of the psoas muscle which projects into the pelvis. The kidneys also rest upon this shelf, being held back normally by the retroperitoneal connective tissue. In the normal individual, therefore, the kidney has no tendency toward prolapse, and the same may be said of the ascending colon which is held fast by fusion with the parietal peritoneum. The abdominal wall in front of these organs restrains them from slipping downward upon this inclined shelf.

b. Suspensory System.—Investigating next the suspensory supporting system of the organs within the abdominal cavity we find that much less reliance is to be placed upon it for the support of weight. Aside from the connecting blood vessels and nerves coming from the posterior abdominal wall, the only suspension support of the abdominal organs comes from the peritoneal layers of the mesentery. The liver is actually fused with the diaphragm posteriorly.

Its free margin is supported in the middle by a part of the primitive ventral mesogastrium in form of the falciform ligament. The stomach is suspended from above by the esophagus and the gastrosplenic ligament lying principally to the left of the median line. The body of the stomach is suspended from the lesser curvature by the hepatic ligament. The mesentery for the small intestine again is relaxed and long, and allows considerable freedom of motion, becoming tighter only at the ileocecal valve. Then again the cecum and the ascending colon have their mesentery partially fused to the parietal peritoneum. Only in its transverse part the colon is free to sag into the lower portion of the abdomen. Again at the sigmoid flexure the long mesentery begins, and after forming a fan-shaped loop or two, returns to the left iliac region, where it is attached to the pelvis just below the psoas muscle.

In a study of the anatomic basis of the splanchnoptosis Vietor[26] points to the great number of variations not only in the arrangement of the colon, but also in that of the sigmoid and the small intestine, some of which decidedly predispose to the displacement. According to Lane, in the erect position cecum and ascending colon become filled more or less with fecal contents, gradually dilating and exhausting the muscular wall. As the dilated cecum is displaced downward into the true pelvis, its presence materially interferes with the function of other organs whose assigned place is the true pelvis. The downward displacement of these organs into the true pelvis relieves the flare of the os ilei and the anterior abdominal wall from bearing their weight, but this is deflected against the pelvic floor so that the latter now is under additional weight bearing stress. Another intraabdominal cause for enteroptosis is seen in pathologic bands and membranes, restricting the ascending colon, and known as Jackson's membranes. Still another obstacle is seen in the so-called sigmoid kinks described by Lane. Patients with sigmoid complications complain of discomfort, flatulence, and frequent desires at stool.

There are a great many other variations due to nonfusion of the parietal peritoneum. They usually are congenital developmental anomalies and they seem to attain at times some significance in enteroptosis and constipation.

According to Coffey[8] seven-eights of the weight of the abdominal organs is either borne by the psoas shelf, or indirectly by the abdominal wall. Only one-eighth of the weight is borne by the suspensory ligaments.

c. Support by Abdominal Wall.—It is now possible to appreciate the fact that the muscles of the abdominal wall are the principal factors in maintaining abdominal balance. With its elastic and contractile resistance the abdominal wall restrains the abdominal organs from being forced downward by their own weight and by the pressing effect of the descending diaphragm.

Again, since the abdominal muscles are attached to the thoracic cage and since the latter is balanced in a slightly inspiratory position, one may rightly say that the thoracic cage on its part contributes to the support of the abdominal organs by pulling up the abdominal muscles and keeping them in better state of tension. The more the respiratory balance of the thorax inclines toward the inspiratory side, in other words, the higher the ribs are held normally, the better is the situation for the abdominal muscles, and the better are these able to sustain the visceral pressure. If, on the other hand, for some reason the inspiratory balance of the thorax is shifted more to the expiratory side, that is to say, if the ribs take more of a downward slant, then the chest becomes flatter and accordingly the inspiratory excursion becomes less; then, also, the abdominal tone becomes weaker and the muscles less able to resist the stresses of the abdominal organs.

d. Discrepancies of Opinions on Significance of Anatomic Variations.—Some radiologists (Baetjer) distinguish between normal and pathologic visceroptosis. In the pathologic type the position of the intestinal tract may be the same as physiologically, but shows marked evidence of sluggishness, stasis and tension. Most radiologists also believe that the anatomic position of the gastrointestinal tract plays very little part in the production of pathologic changes of the spine.

From the internists' point of view it is maintained (Bettmann[2]) that the position of the stomach proves little as to its function and the same is asserted of the colon which within a few hours after ingestion may assume many different positions without showing signs of stasis (J. C. Case). Some authors consider it a crude notion to believe that the prolapsing colon produces kinks which obstruct, and produce stasis.

Attention is further called by Keith to the fact that there is no hypertrophy of the muscular coat about the sides of the so-called bends or kinks. Considering the physiologic mechanism by which the contents of the colon are removed and propelled by an enormous mass of muscle fibers equal in volume to the biceps, variations in position have little effect upon the function of the colon.

e. Intraabdominal Pressure and Abdominal Function.—These few instances are cited to give air to the many objections which have been raised against bringing faulty abdominal mechanics into relation with deficiency of the gastrointestinal tract. The point that most of the objectors seem to neglect is, that it is not only, nor principally, the positions of the organs within the abdominal cavity but rather the periodic fall and rise of the interabdominal pressure to and from its normal limits which is essential for the function of the abdominal organs. An organ placed in the abdominal cavity may become accustomed to any position provided it is held in balance. It is just this instability of the abdominal balance as represented by the condition of visceroptosis which gives the situation a pathologic significance. The abnormal downward pressure is not constant but is forever increasing and the situation is comparable to that of an abdominal hernia.

3. The Clinical Types of Visceroptosis

From the orthopedists' standpoint we are especially interested in such types of enteroptosis as have their primary cause not in intraabdominal conditions such as kinks and bands, but in the disturbance of the body balance as a whole and of the abdominal balance in particular. We distinguish the following groups:

a. **The relaxation or paralysis** of the abdominal walls with respiratory debility. To this group belong all cases of relaxation of abdominal walls following infantile paralysis (Plate XI, 4, 5). The paralysis is seldom confined to abdominal muscles alone, the auxiliary respiratory muscles of the thorax are likewise involved. The relaxed abdominal musculature bulges forward at the point of greatest strain, that is, in the lower portion of the abdomen below the umbilicus. As the weakness of the abdominal muscles makes it impossible to develop proper abdominal pressure, the respiration also becomes more shallow, since the expiratory backstroke furnished normally by the interabdominal pressure is impaired. The contractures of the diaphragm force the abdominal contents downward and forward in inspiration but there is no sufficient abdominal pressure for the proper recoil when expiration begins; as a result, the diaphragm moves up and down at a lower level. Furthermore, the abdominal pressure necessary for the evacuation of the abdominal contents is lacking and the patients are subject to constipation. The dilated hollow organs become more and more atonic and sagging, straining the abdominal wall and so a complete vicious circle is established.

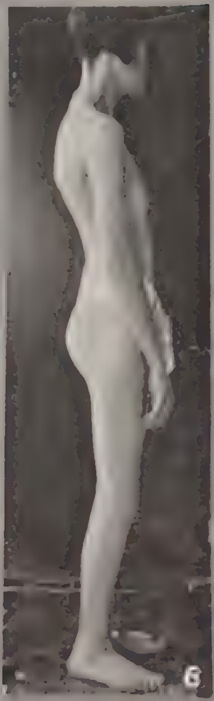
Since the abdominal protrusion causes the patients to appear hollow in the lower portion of the back, the upper portion of the thorax is correspondingly thrown backward; and since the auxiliary respiratory muscles such as the pectoralis are weakened, and the elevation of the ribs in inspiration is deficient, the thorax by its own weight is gradually pulled downward into a more and more expiratory position.

Next to the abdominal wall the tone of the muscles composing the pelvic floor must be considered. Normally the strain placed upon the pelvis is dependent greatly upon the inclination of the pelvis, that is, the angle of the pelvis forms with the horizontal. If the inclinatory angle is small, that is, if the aperture of the true pelvis approaches more the horizontal, then the weight of the superincumbent abdominal organs bears directly upon the pelvic floor; whereas, if the inclinatory angle is greater than the pelvic floor approaches more the vertical planes, then a larger portion of the weight of the abdominal organs will come to rest upon the symphysis and the lower anterior abdominal wall. We consequently find the flat back more prone to develop relaxation and sagging of the pelvic floor as a feature of general visceroptosis, than the back with the hollow lumbar spine.

b. **Visceroptosis as a Symptom of Faulty Posture.**—In the previous paragraph attention was called to the fact that postural anomalies acquired in youth are very apt to predispose to visceroptosis. It is especially noticeable in the types of malposture in which the upper portion of the trunk is thrown backward as seen in asthenic maldeveloped individuals with weak musculature as well as in the postural anomalies of rickets (Plate XI, 6). Osgood[19] is convinced that a marked degree of visceroptosis may exist and yet the individual may be entirely symptomless. Sever's statistics in children show

PLATE XIII

Fig. 1.—Enteroptosis exercises. Back muscle development.
Fig. 2.—Anterior abdominal muscle development.
Fig. 3.—Anterior abdominal muscle development.
Fig. 4.—Lateral and anterior abdominal muscle development.
Fig. 5.—Shoulder girdle exercises.
Fig. 6.—Visceroptosis in arthritis.
Fig. 7.—Visceroptosis in arthritis.



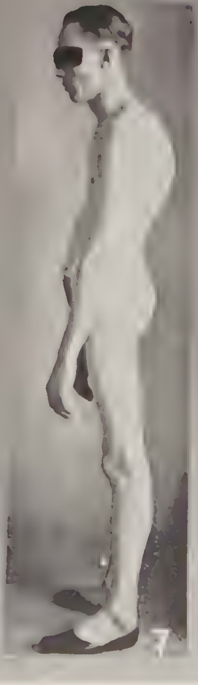


PLATE XIII

that the incidence of visceroptosis is great, and recent observations of Lewis demonstrated its frequent occurrence among high school boys. From 30 to 60 per cent of children were found to have bad posture, poor muscles, poor nutrition, prominent abdomen, and ptosis without being sick. On the other hand, it is certain that too many cases of visceroptosis represent symptoms of various kinds, to evade the impression that there is a close connection between visceroptosis and poor health. Kocher believes that ptosis almost invariably precedes by many years the onset of circulatory and nervous digestive symptoms.

In adults ptosis is frequently found in sufferers from asthenia and other muscular and vasomotor conditions. According to Osgood there is, on the whole, sufficient evidence regarding the causal relation of visceroptosis to certain specific diseases, and from the orthopedic point of view, it is of definite causative and clinical significance. Osgood cites cases of epilepsy and progressive muscular dystrophy which had become arrested over a period of years, and cases of chronic arthritis which steadily improved after orthopedic treatment for visceroptosis.

c. Visceroptosis in Arthritis.—Another important group we find among patients suffering from arthritis with visceroptosis. It is easy to see how the arthritic spine, developing a kyphotic deformity or ''poker-back,'' may be responsible for elementary changes in balance of posture, respiration, and abdominal pressure. The great loss in the respiratory excursion of the thoracic cage which appears flat and narrow, commits such patients to a state of visceroptosis from which they can no longer be rescued when the permanent stages of deformity are reached, because the correction of the forward flexed trunk is no longer obtainable. Furthermore, because of the inability of the ribs to move upward into a more normal level of inspiration the thorax no longer assists in supporting the weight of the abdominal organs. Naturally the persistent weight of the abdominal organs tire the abdominal muscles, their tone gradually becomes lessened, and the principal condition for ptosis of the abdominal organs is thereby established. In such cases of arthritic visceroptosis we also find constipation as a prominent symptom. The pelvic floor appears greatly relaxed and uterine symptoms such as retroflexion and dysmenorrhea are not infrequently encountered (Plate XIII, 6, 7; Plate XIV. 1).

d. A fourth well established type of visceroptosis is seen in **rachitics**: flat chest, pendulous abdomen, round or round hollow back are characteristic features, associated with other rachitic stigmata (Plate XIV, 3).

4. The Treatment of Visceroptosis

The plan of treatment may be divided into prophylaxis and relief measures.

a. The **prophylaxis** lies in the correction of faulty posture which is the most frequent forerunner of visceroptosis. With the body straight, the head extended, the patient rising on his toes, all elements which contribute to the support of the viscera, including their own suspensory apparatus, are working at best. It may be said, rightfully, that visceroptosis begins at the larynx, and that the weight of the viscera is partly suspended from the neck.

b. Correction.—The maintenance of proper posture, including active exercises of the thoracic muscles, with or without resistance, must be carried out assiduously. These exercises also serve the improvement of the respiratory excursion and the restoration of the thoracic balance, while special abdominal exercises must develop the strength of the abdominal muscles, including the diaphragm and the pelvic floor. When such typical breathing exercises and other gymnastic work, designed to improve the function of the thoracohumeral and thoracoscapular musculature, are combined with appropriate postural training, one will soon see that the respiratory excursion increases, provided there are, as yet, no pathologic changes which tend to ankylose the intervertebral and costovertebral articulations. The beneficial effect of this type of gymnastics is especially evident in cases of rachitic malposture, and in visceroptosis of the habitual type, less so in the paralytic and arthritic types of visceroptosis.

The abdominal balance requires particular attention. In postural self-correction a good deal of abdominal muscle training is included. Active exercises of the abdominal muscles, setting up exercises, hip flexion, chest weight and rowing exercises, swimming, etc., all meet the purpose when prescribed wisely and judiciously (Plate XII, 1; Plate XIII, 1, 2, 3, 4).

c. Support.—It is important to remember that the relaxed abdominal muscles in the more advanced cases of enteroptosis need temporary support even more than training and exercises. There are a number of abdominal bandages and belts in use. The principal function of a belt is to exert sufficient and evenly distributed pressure upon the abdominal wall, upward and backward. Such a belt must be wide enough in front to reach from the symphysis to the umbilicus, or higher up to the lower border of the ribs. In the back it is fitted to support the entire lumbar spine and it carries perineal straps to prevent it from slipping upward (Plate XIV, 2).

In all cases in which muscular control of the spine is not perfect, a corset should be given instead of a belt. This has the same function, but reaches higher up in the back, and, being provided with shoulder straps insures proper posture (Plate XII, 5).

d. Elimination.—The proper evacuation of the contents of the hollow abdominal viscera is greatly aided by the systematic development of abdominal muscles and diaphragm action. This, however, is not sufficient in the beginning of the treatment. In all patients with intestinal stasis a thorough cleaning out by mild cathartics or colonic flushings should be used. Then systematic abdominal massage should be applied to stimulate the peristalsis of the intestines, especially of the colon.

A diet must be prescribed which is mildly laxative, preferably one rich in cellulose and poor in carbohydrates; fresh vegetables, bran bread or whole wheat bread, cereals, fruit, make up the bulk of this diet.

PLATE XIV

Fig. 1.—Visceroptosis in arthritis.

Fig. 2.—Supportive belts. (See also Plate XII, Fig. 5.)

Fig. 3.—Visceroptosis in late rickets. Visceroptosis in faulty posture.

Fig. 4.—Congenital funnel chest. No evidence of rickets. Deformity present since birth.

Fig. 5.—Patient of Fig. 4.

Fig. 6.—Visceroptosis in faulty posture produced by bilateral congenital dislocation of the hips.

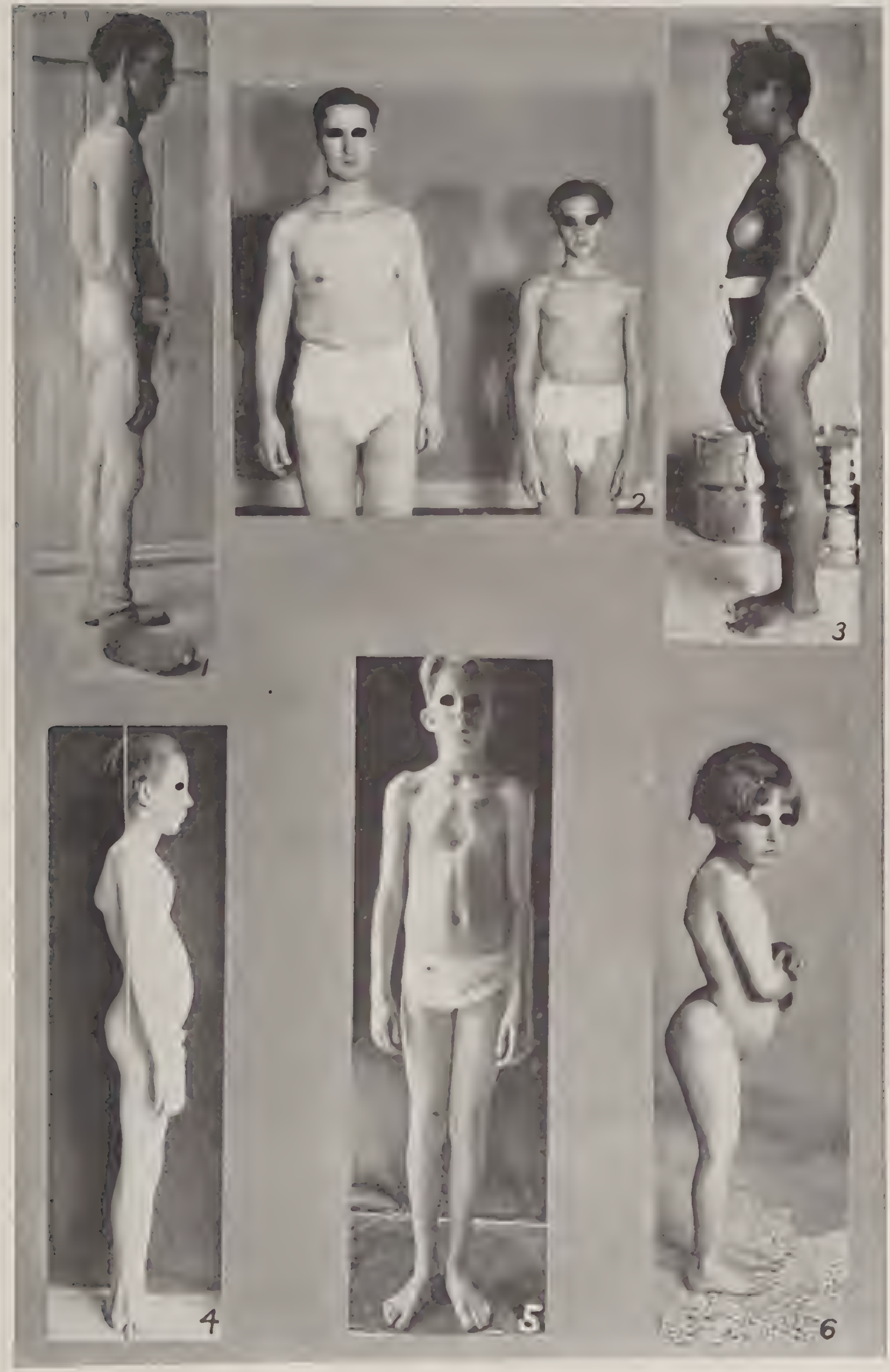


PLATE XIV

In view of the general debility, we believe it unwise to restrict the number of calories, nor is there any special advantage in the withdrawal of protein. Protein may be given freely even to those patients in whom an arthritic element exists.

The abdominal massage should be carried out once a day and should be accompanied by active muscle exercises.

The effect of operative measures upon visceroptosis, in so far as they do not meet strictly localized conditions, is still problematic.

For the development of the muscles of the pelvic floor, sprays and sitz baths are recommended. Exercises should be carried out also in the knee-chest position, in addition to the ones already described for respiratory and abdominal balance. The tone of the pelvic floor being an essential part in the restoration of the general body balance, it is important to give to these special exercises particular attention.

e. General Régime.—To this belong such local operative measures as will improve the freedom of the upper air passages, the removal of tonsils, adenoids, clearing of sinuses. Fresh air and proper feeding are also important factors in the treatment, when the patient is restored to greater activity. Nourishing and fat-forming food should be prescribed, since accumulation of fat in the abdominal cavity is an essential factor in supporting intraabdominal weight, and since in many cases enteroptosis takes its incipiency from loss of weight and fat absorption with subsequent relaxation.

IV. STATIC CONSTITUTIONAL ANTEROPOSTERIOR DEFORMITIES

1. The Rachitic Kyphosis

a. Pathogenesis.—The rachitic kyphosis owes its being to the general organic changes which characterize rickets. Without these as background, the infant would succeed in developing the adequate lumbar lordosis which is the normal effect of the straightening of the body when the static functions of sitting and standing begin. From the mechanistic point of view, rachitic kyphosis is the remainder of the normal physiologic anteroposterior curve of the newborn child. Owing to the softness of bone and especially to the weakness and relaxation of the muscles of the back, the erection of a spine by the latter muscles is not accomplished. While the upper portion of the thorax is held back, the lower dorsal and lumbar regions yield to the superincumbent body weight by formation of a lumbodorsal kyphosis, the characteristic rachitic back (Plate XIV, 3).

As the child begins to stand up and walk an attempt is made to recover balance by compensating the low dorsal and upper lumbar rachitic curve by a low lumbar lordosis, so that later the typical malposture is that of a round back, or round hollow back.

b. Pathology.—The nature of this malposture is revealed by rachitic stigmata. The thorax appears compressed from side to side, most markedly in the middorsal region, and the sternum may be unduly prominent in front so that the anteroposterior diameter of the chest even exceeds the lateral one (Freiberg[10a]). In younger children evidence of rickets is seen in the persistence of a rosary or in the transverse constriction of the chest, the so-called Harrison's groove just below the nipples. Owing to the long-continued forward flexed position of the thorax at early age, and to the great plasticity of the skeleton, the secondary rachitic changes of the thorax are usually well marked. The most frequent form is the pectus excavatum or funnel chest. Here, the sternum appears depressed below its normal level carrying with it the costal cartilages attached to it. The lateral diameter of the thorax is greatly increased over the anteroposterior. Most of the cases of true funnel chest are of congenital character (see Chapter I, and Plate XIV, 4, 5), but depression of the lower end of the sternum without formation of a true groove of the sternum is noted in almost all cases of rachitic round back.

The x-ray pictures show the vertebrae deformed in the characeristic wedge-shape without any particular disturbances of the epiphyses, as is observed in cases of true epiphysitis. The anterior contours of the vertebrae are usually rounded, the intervertebral spaces are high, and there are no signs of collapse or fusion of the bodies.

c. The Treatment.—The treatment of the rachitic round back so far as it requires local attention falls in line with that of the round back in general. Development of the musculature, the support of the back by proper retentive apparatus are the two most important principles. The treatment must always be supported by appropriate general treatment directed first against the metabolic changes of rickets in the florid stage and against the subsequent impairmen of the general nutrition afterward.

2. Osteochondritis Deformans Dorsalis; synonym: Vertebral Epiphysitis

a. Historical.—Our knowledge of the anteroposterior deformities of the spine has become enlarged in later years by isolation, out of this group, of a type of cases occurring during juvenile and adolescent age and presenting a certain pathologic anatomic entity. This is a condition first described by Scheuermann[23] and Delahaye[9] under the name of osteochondritis dorsalis juvenilis. Heretofore, in discussing the anteroposterior deformities of this age, occurring without definite etiologic identity one was content to assume a state of lowered resistance of the spine against functional requirements which was accentuated during the critical period of age, and in addition, some inherent weakness or insufficiency of the spine was perhaps admitted (Schanz[21, 22]).

When it was found, however, that individuals afflicted with anteroposterior deformity or dorsum rotundum are often of athletic build and that they are endowed with a strong muscular and osseous system, the mere static-mechanical explanation of the development of this deformity became unsatisfactory, and one began to look for more specific causes.

As early as 1916, H. Virchow[27] described what he called a wearing off of the anterior edges of the vertebral bodies. He found this condition in the Australian negroes, who from their early adolescence are in the habit of carrying weights upon their shoulders, or of pulling carts with forward flexed trunk. The condition pointed toward the development of the vertebral epiphyses, and disturbance in the normal ossification of the vertebrae was suspected.

As already explained, under normal conditions the ossification of the vertebral bodies occurs from three bony centers, one in the body and two in the arches, which gradually increase until arches and body become united, somewhere between the third and eighth year of life. After this the body of the vertebrae depends for its further growth upon periosteal bone formation. The length growth of the vertebral bodies, however, is taken care of by epiphyseal ossification. At the time of puberty, that is, about the fourteenth year of life, there appears, according to Koehler,[15] at the upper and lower anterior edges of the vertebral bodies a small triangular x-ray shadow representing the first signs of the epiphyseal ring. These ring-shaped formations gradually project farther back, thinning out in a fine line and assuming greater thickness again at the posterior edges of the vertebral bodies. This ring remains separated from the body of the vertebrae until the time of fusion, which, according to Schulthess,[23a] is at the twenty-fifth year, according to others, the twenty-second to twenty-fourth year of life. At this time the length growth of the vertebral bodies is concluded. It seems now that under certain conditions the normal epiphyseal ossification of the vertebral body becomes disturbed. Scheuermann, in his cases, found that the vertebral bodies were lower in front and the epiphyseal disc appeared broad and irregular. The epiphyses themselves appeared irregular and fragmented, their contours were blurred and indistinct. He, therefore, inferred that the primary effect of the condition was disturbance of the epiphyseal growth. In later stages it was found that the epiphyseal ring again assumes more definite contours, that its irregular fragmentation disappears and that it becomes solid. He, therefore, named the condition "Osteochondritis Deformans Juvenilis," having in mind the analogy to Legg-Calvé-Perthes' disease or osteochondritis deformans of the hip as well as the similarity to Koehler's disease of the scaphoid, and Freiberg's disease of the metatarsal head. Mau,[17] who made a close study of the condition, also points out to the irregularity in contour of the vertebral body, to the wavy outline seen between the upper and lower contour of the body and the epiphyses, and the frequent fragmentation of the epiphyseal body. Buchman,[5, 6] examining sixty-five cases of so-called idiopathic anteroposterior and lateral curves of the spine, found positive evidence of an epiphyseal disease in 83 per cent of the cases, and he also considers this the primary lesion.

b. Pathology.—According to Mau[17] there are three stages: a period of irritation, a period of destruction, and a period of reparation.

In the earlier stages of the disease there is a vertebral epiphyseal plate which appears rarefied, and the outlines are frayed and motheaten. This makes the intervertebral spaces appear irregular and mottled, and the adjacent vertebral borders indistinct; then comes the stage where it is difficult to differentiate the intervertebral spaces from the bodies, as in the lateral view everything appears as a continuous fused mass. Later again the vertebral outlines become more distinct, but they are still irregular; the epiphysis now becomes differentiated and appears as a dense shadow although not returning to its normal size; at the conclusion of the growing age this stage of ossification is also concluded and the progress of the deformity is thereby checked.

c. **Microscopic Findings.**—Mau found an enlargement of the cartilage cells and a stratum of nondescript deposits of lime salts, but no new formation of blood vessels, and no real ossification process. Blood vessels, however, may grow in from the perichondrium toward the point of ossification, a triangular mass of spongeous bone which is separated by a layer of cartilage from the spongeous mass of the body of the vertebrae. The growing islands of ossification establish layers between epiphysis and body, the interspace between them becomes more and more reduced and finally disappears, and both body and epiphysis become synostotic. This synostosis of the epiphysis with the body also occurs earlier in the female sex than in the male (Kochs[14]) and on an average becomes completed between the twentieth and twenty-fourth year.

d. **Pathogenesis.**—The question arises, what is the pathologic anatomic basis of the changes seen in the epiphysis of the vertebral bodies in an adolescent kyphosis?

Most of the observers agree with Scheuermann, who ranks these disturbances as akin to Calvé-Perthes' disease, and Koehler's disease, that is, a primary disturbance of the ossification process in the epiphysis. He recognizes in this condition the same cycle as seen in the osteochondritis deformans of the hip, and similar conditions. It is assumed, by the majority of observers, that there is a disturbance in formation rather than an aseptic necrosis secondary to vascular changes in the sense of Axhausen. On the other hand, the x-ray findings are very suggestive of the findings seen in late rickets, especially the blurring, the mottled atrophy and the changes in enchondrial ossification. From this viewpoint the deformity may be classified as a weight-bearing deformity upon a rachitic or osteomalacic basis. Mau[17] likewise believes that the condition ranks with osteochondritis deformans of the hip, but he does not admit an epiphyseal necrosis. He rather believes that this condition is a manifestation of a late rachitic weight-bearing deformity. In this sense the theory of Jansen deserves mention, which speaks of an insufficiency of the skeleton being produced by hyper-vitality and vulnerability of rapidly growing cells. The disease is to him a manifestation or expression of feebleness of growth, and the fact that the trouble occurs during adolescence fits in with his conception that the vulnerability of the tissues is proportionate to the rapidity of growth. On the other hand, it must be understood that rapid growth and

PLATE XV

Fig. 1.—Vertebral epiphysitis. Note round back. (See X-ray Fig. 4.)

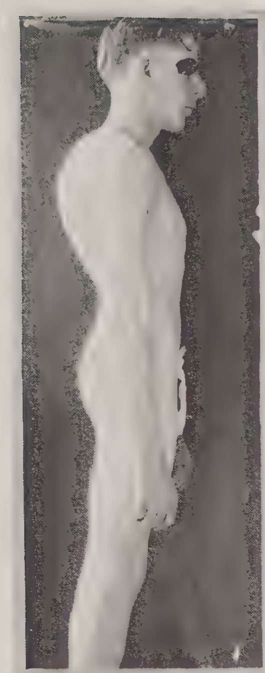
Fig. 2.—Vertebral epiphysitis. Note round back. (See X-ray Fig. 5.)

Fig. 3.—Detail of lumbar spine of another case of vertebral epiphysitis. Note fragmentation of epiphyses.

Fig. 4.—Lateral x-rays of patient in Fig. 1. Note fragmentation of epiphyses.

Fig. 5.—Lateral x-rays of patient in Fig. 2. Note fragmentation of epiphyses.

Fig. 6.—Anteroposterior view of case of Fig. 3. Note irregular contours, flattening of bodies, broadening of sacro-iliac joint spaces.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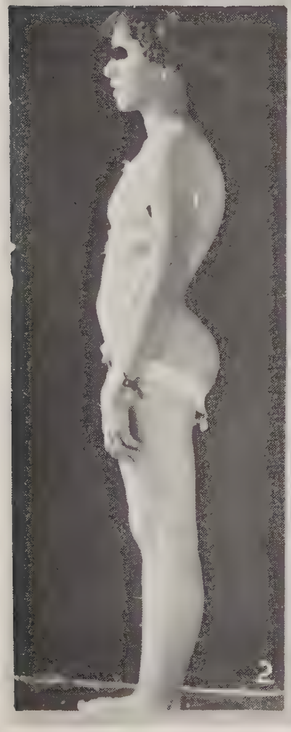
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PLATE XV

inherent vulnerability of the cells are not in themselves sufficient reason to explain these disturbances in ossification.

According to Wolf[29, 30] the adaptability of bone during the formative period is equal to the mechanical stresses imposed upon it. The power and rapidity of the transforming process keeps step with the increased mechanical requirements. We certainly do not see in normal growing bone any inability on the part of the tissues to adapt themselves to increased functional requirements. Obviously there is some factor at work which accentuates the reaction of the growing cartilage to static stresses; such a factor might well be a deficiency in ossification and lime salts as it is observed in rickets. Looking about for such an additional etiologic factor we may first mention a theory of Axhausen,[1] who considers the condition as one of aseptic necrosis produced by circulatory disturbances without the existence of an inflammatory process of infectious origin. Pressure fractures, due to mechanical strains and stresses, may have part in the disturbance of ossification, but they, themselves again, must be the effect of an underlying cause which renders the resistance to stresses below par. There has been, up to this date, no evidence adduced of the infectious nature of this condition.

In default of better reasons, there seems to be no objection, then, to classify the condition with late rickets, or with other weight-bearing deformity of adolescence, such as genu varum, genu valgum, or coxa vara; but conclusive evidence could only be found by establishing chemical changes similar to those in manifest rickets.

e. Clinical Symptoms.—We are dealing with an anteroposterior deformity of the spine occurring at the age of puberty and progressing more or less rapidly. It is a self-limited affection of the epiphyses of the vertebral bodies in the dorsal region, although according to Buchman,[5, 6] other epiphyses such as those of the iliac crest or other parts of the skeleton may be involved concomitantly. The condition starts between the ages of twelve and sixteen; the onset is usually marked by extensive fatigue, backache, and pain in the limbs. Occasionally there is tenderness over the spinous processes of the involved vertebrae. In due time a deformity of the anteroposterior type develops. It is this deformity which forms the most obnoxious factor in the clinical syndrome, and for which medical help is usually sought. The disease runs a limited cycle as evidenced in the x-ray changes; within a certain length of time, usually after two or three years, the deformity becomes entirely stationary, rigid, and the subjective symptoms completely disappear (Plate XV, 1-6; Plate XVI, 1, 4).

f. Treatment.—Since nothing is known definitely regarding the etiology of the condition, the treatment can only be symptomatic. The back must be supported by means of adequate braces or plaster of Paris casts. Braces of the so-called spring-back brace type, or of the modified Goldthwaite type containing a base band which encircles the body between the iliac crests and greater trochanter, and is equipped with uprights and shoulder straps at the upper end, are suitable contrivances.

The musculature of the back which becomes inefficient during the active period of the disease must be given attention. Massage, postural exercises, and especially breathing exercises should be instituted within the limits of tolerance.

After the braces have been worn for one or two years they may be exchanged for a corset also provided with shoulder straps which assist in the maintenance of the proper position.

3. The Osteochondritis Vertebrae

a. Pathology.—This is a condition similar to the foregoing but is different in its localization.

In an article entitled "A Localized Affection of the Spine Suggesting Osteochondritis of the Vertebral Bodies with the Clinical Aspect of Pott's Disease," Calvé[7] submits two observations of his own and another of Brackett, of Boston, in which the clinical picture was very suggestive of tuberculosis of the spine. In the x-ray picture this author found, in striking contrast to the findings in Pott's disease, an absolutely intact condition of the adjacent intervertebral discs above and below the diseased vertebra. The cartilage appeared thicker and there was new formation of tissue causing the interspace to appear higher than usual. The vertebral bodies, however, showed greater opacity than normal. Buchman[5] describes the condition as an entity, entirely distinct from the epiphysitis, in that the pathologic process is situated in the ossification area of the vertebral body itself. The x-ray picture is characterized by the irregularity in the outlines of the vertebral bodies which appear blurred and fragmented; only later, when the process of reparation and restoration sets in, the vertebral outlines again become sharp and the entire body of the vertebra is more sclerosed. By this time, however, a deformity of the vertebral body has developed under weight-bearing stress resulting in a wedge formation of the body (Plate XVI, 2, 3, 5, 6). In Calvé's cases only one vertebra was involved and showed a cuneiform shape. There was the same period of fragmentation in the vertebral bodies which is seen in vertebral epiphysitis; later the bone returns from a state of fragmentation to that of greater density, and in the x-ray picture taken at this stage, the shadows of the vertebral body become heavier than normal.

b. Symptoms.—This condition sets in much earlier than the vertebral epiphysitis; it is characterized clinically by slight pains, fatigue, sometimes night cries, muscle spasm and tenderness.

c. Treatment.—The treatment consists in the application of corrective plaster casts during the acute stage, later in the use of braces. All of Buchman's cases were treated by recumbency and plaster jackets, and all of them had some residual deformity of the spine, which, however, did not interfere with its function.

PLATE XVI

Fig. 1.—Vertebral epiphysitis with nontraumatic bilateral separation of femoral epiphyses. Note external rotation of femurs. Spine. X-ray of Fig. 4.

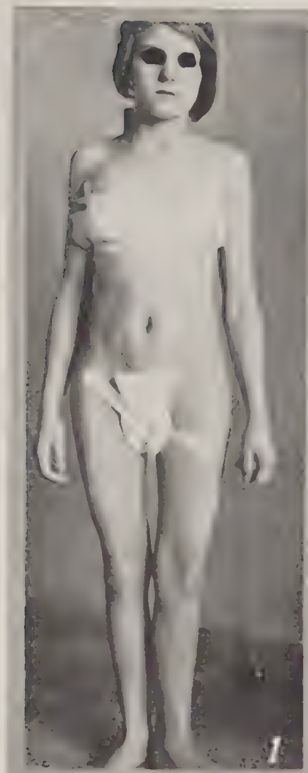
Fig. 2.—Osteochondritis vertebrae. Patient of x-ray of Fig. 5. Note angulation in lower dorsal region.

Fig. 3.—Osteochondritis vertebrae. Similar low dorsal angulation. X-rays in Fig. 6.

Fig. 4.—Vertebral epiphysitis. Lateral view of patient in Fig. 1.

Fig. 5.—Osteochondritis vertebrae. Note 12th dorsal cuneiform shape. Sharply outlined. Not congenital. Not tuberculous. Patient of Fig. 2.

Fig. 6.—Osteochondritis vertebrae. Wedging of 1st lumbar. Not tuberculous. Not congenital. Patient of Fig. 3.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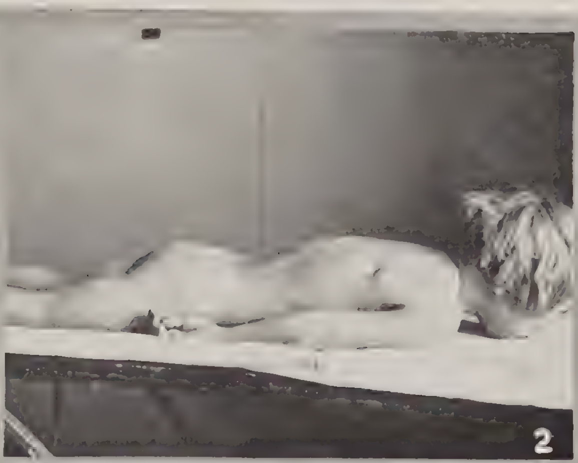
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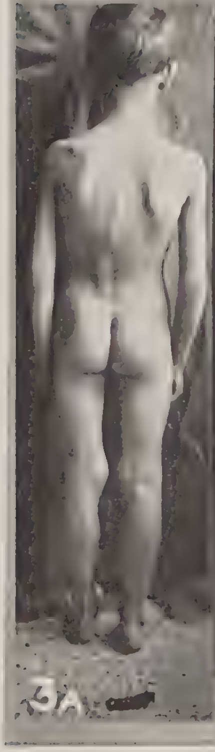
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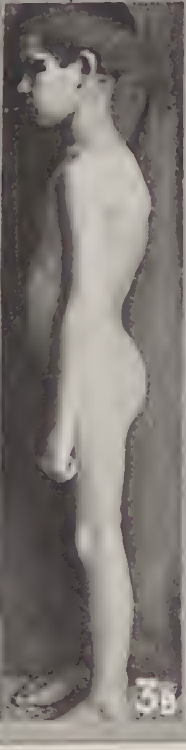
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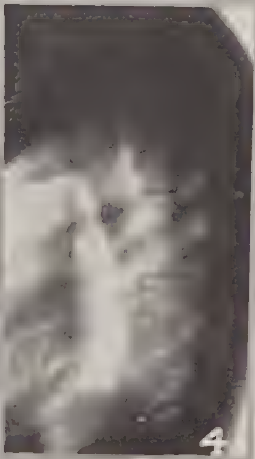
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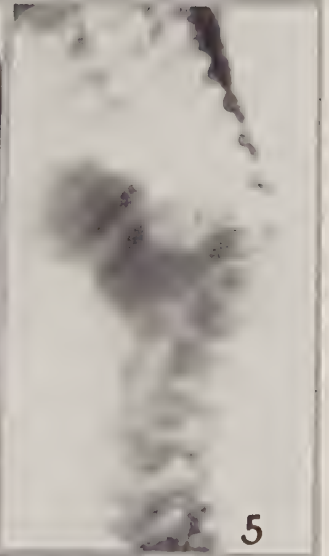
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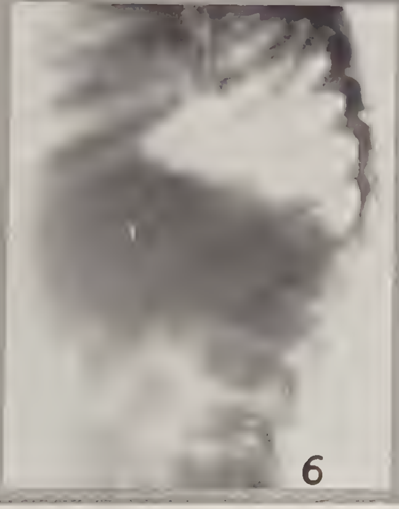
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PLATE XVI

V. COMMENT ON CHAPTER II: STATIC ANTEROPOSTERIOR DEFORMITIES

The normal balance of the body is conditional upon a certain proper relation between three mechanical units: a primary, the spine; two secondary, the thoracic cage and the abdominal cavity. This relationship necessitates that a change in one of the systems carry with it changes in the others, and that the normal balance in one cannot be relinquished without a similar effect upon the others.

Primarily, the loss of balance may be the result of the spine losing its normal equilibrium; thorax and abdomen are involved secondarily; malposture, or the loss of balance, may be the result primarily of relaxation of the abdominall wall, and thorax and spine follow in the overthrow of balance: Visceroptosis.

There are different types of malposture according to the anatomic build of the individual, predisposing to one type or the other, and, according to the manner in which the spine endeavors and is able to find a secondary equilibrium: viz., the round back, round hollow back, the rachitic kyphosis, or the osteochondritic back. There are, also, corresponding types in Visceroptosis, according to the factors underlying the abdominal insufficiency: postural, arthritic, or paralytic visceroptosis.

At all events, the treatment and management must be concerned principally with the restoration of normal balance in all three systems: spine, thorax, and abdomen, at the same time by muscle development, exercises and proper hygiene and nutrition. Supports or braces are temporary, applied pending the development of active balance. Only in cases with progressive tendencies in which, due to age, duration, or nature of the condition, no return to a stable balance can be expected, one must compromise with relief instead of cure and appliances are necessary for longer periods or permanently.

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CHAPTER III

SCOLIOSIS. SYNONYM: LATERAL DEFORMITY OF THE SPINE

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   2. Distribution Mechanism of Stress
   3. Intrinsic Vertebral Structure, Trabecular System
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   6. Passive Equilibrium of Spine
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XII. Comment on Chapter III: Scoliosis

I. INTRODUCTION

We know of no other type of deformity that presents a similar amount of intricate and complex problems. There is also no other condition in orthopedic surgery which has received the same degree of interest and investigation. The great wealth of literature which has been woven around the subject might embarrass the most assiduous reader. Yet, should he conquer his reluctance and approach the subject with determination he will find himself rewarded. The study of the topic will lead him back to the oldest times of medical endeavor and it will unfold before him a continuous change of theoretic conceptions and practical ideas, which, like few other events, mirror the evolution of medical thinking. One might say the history of scoliosis is a microcosmus of the evolution of medical thought condensed into a single narrow field of surgery.

HISTORICAL

We can trace the recognition of this deformity as far back as Hippocrates.[57] He was the first to use the term ''Scoliosis,'' then applied indiscriminately to all kinds of disalignments of the back. However, he already distinguishes between anteroposterior deformity, which he considers dangerous because of the retention of urine and loss of sensation (paralysis in Potts' disease), and the so-called outer curves, which he considers more harmless (lateral curvature). We see Paul of Aegina (650), using wooden splints for the correction of this deformity, and we read that Albucasen (1150), knew this deformity and considered it an incurable condition.

Probably the first accurate description of scoliosis we owe to Ambroise Paré[107] (1510-1590). He recognizes the progressive tendency of the deformity and tries to meet the situation with an iron brace, which, for these early times, remains a remarkable piece of construction. The sixteenth and most of the seventeenth centuries remain silent on the question of scoliosis, except that it is mentioned by Pineus (1641), who remarks upon its frequency.

An early autopsy performed by Hildanus in 1641 brought no further information, but when, during an epidemic of rickets in England, a committee was appointed to study this condition with Glisson at the head (1660), this deformity of the spine was described and measures recommended for its relief.

More explicit descriptions are found in the eighteenth century. André (1741) gives a detailed account of the deformity, correlating different postural and vestimentary influences. It was Percival Potts (1779), however, who, from the unclassified group of spinal deformities, singled out the anterior as well as the lateral curve, and published the result of his investigation in a classic treatise on ''Palsey of the Lower Limbs in Consequence of Curvature of the Spine.''

In the meantime the existence of a physiologic lateral asymmetry of the spine did not escape the attention of the anatomists. Bichat[13] believed that the location of the aorta at the left side of the spinal column caused a slight deviation of the normal spine to the right; Sabatier,[123] on the other hand, was of the opinion that this asymmetry was due to right-handedness; and, though both explanations might be challenged, the observations themselves are probably correct.

So far only the gross anatomic features of the deformity had been given consideration. Early in the nineteenth century, however, contributions were made relative to the congenital changes of the spine and their relation to other developmental disturbances (Hermann, Fleischmann).

Little had been published up to this time in regard to the causation of the deformity. Hippocrates considered the deformities of the spine as dislocations, and Galen (200 A.D.) as vestimentary deformities, but, aside from these sporadic expressions on the pathogenesis, nothing was heard until the nineteenth century, when Stromeyer's theory of the inequality of the ribs appeared. In 1836 he came out with his conception of the primary asymmetry of the ribs as the cause of scoliosis. From that time on the pathogenesis of the condition fascinated the orthopedic mind, and theories on the developmental mechanism of scoliosis began to pour in in abundance. There followed shortly the work of Guerin,[52, 53] who was the first exponent of a so-called "contractural" theory of scoliosis. Not only did he believe in a primary active contracture as the cause of scoliosis, but he also acted upon this supposition and performed numerous myotomies upon his patients. He was, in theory, though not in practice, supported by the elder Little of England.

When in 1878 L. H. Sayre[125] introduced in this country the plaster jacket as a practical means of dealing with spinal deformities, the interest in scoliosis became revived, and with it further theoretic conceptions of its pathogenesis developed. There were the theories of unequal nutrition of the vertebral halves, of softening of bones, of osteomalacia, caries, rickets, of asymmetries, of intervertebral discs, which followed each other in quick succession. There is no need of dwelling at length upon these rather hazy and impressionistic ideas, while they make interesting reading in that they demonstrate how imagination and the inductive type of reasoning was running ahead of actual experience and observation. Concrete definitions and conceptions began to appear only with the more distinctive and persistent studies of the sixties and seventies of the last century. Bouvier[19] was one of the principal investigators of the clinical side of scoliosis and his lectures on the clinics, mechanics, and pathology of the condition rank far above any other contemporary achievement in this field. At the same time the theoretic knowledge of scoliosis was greatly advanced by the splendid investigations of Hermann von Meyer.[97, 98] His work on the mechanics of the condition served as a background and reference for numerous important contributions of the following years, including those of Albert[6, 7, 8] and Riedinger. It was Meyer, who brought into the foreground the mechanistic element, thereby opening the way for the appreciation of other than mere pathologic anatomic influences. In accord with his mechanical conceptions, scoliosis began to be recognized as a weight-bearing deformity (Roser, Volkmann). So the soil was prepared for the classic monograph of Lorenz[87] which appeared in 1886, and which embodies the clinical conceptions of Albert and the theoretic ideas of Meyer, and which, besides, introduced many other points of pathologic significance: the relaxation of the ligamentous apparatus, the effect of posture, of asymmetrical weight-bearing, and the influence of paralytic factors.

From that time on the pathogenic conception of scoliosis began to flow into more modern channels. Mechanistic forces and anatomic substratum were being coordinated (Deutschländer,[28] Schanz). In the field of treatment, however, nothing particular was added after the production of Sayre's plaster jacket until the extension-suspension treatment of Schanz[129, 130] appeared (1900).

Lovett,[91, 92, 94] to whose classic and important investigations on the mechanics of scoliosis, reference will be made later, introduced the prone position into the technic of scoliosis treatment in 1901. The suspension technic in an adjustable frame was practiced by Wullstein[157] (1902). Both used plaster jackets and diagonal pressure for correction. In 1906, Calot,[24] extending his corrective method devised for Potts' disease, also to lateral curvature, presented in his forcible redressment a departure, if not in kind, yet in degree, from the usual course.

Since 1906 the interest in the congenital causes of scoliosis was renewed following a very thorough treatise of Boehm,[15, 16, 17] and the contributions of Putti,[111] and others, on the subject. The appreciation of congenital anomalies and variations has had a very stimulating influence upon recent studies (Willis[154a]), and has resulted in a very wholesome readjustment of the modern pathogenic conceptions of spinal curvature.

Most deeply of all, however, is modern orthopedic surgery indebted to the incessant labor and careful and introspective studies of W. Schulthess[137, 138, 139, 140] of Zürich, the greatest clinical observer of scoliosis of all times. With his great experience, his most careful observations, his patient and most painstaking methods of recording, his ingenious devices in mechanotherapy, and his conservative attitude regarding conclusions and generalizations, he ranks easily as the foremost authority on scoliosis. His numerous publications are mostly of clinical character, but they, as well as those of his pupils, bear the stamp of unusual thoroughness and reliability.

In this country the interest in the subject has been kept alive steadily since the work of L. H. Sayre[125, 126, 127] has received general recognition. Following the important contributions of Lovett,[91, 92, 93, 94] and the classic treatise on scoliosis of H. O. Feiss,[39] many American surgeons (Freiberg,[47] Truslow,[149, 150] and many others) added valuable contributions to our knowledge of the deformity. In later years the treatment of Abbott[1] and that of Klein[77] have aroused more than usual attention. On the operative side of the problem the names of McKenzie-Forbes,[43] Hibbs,[55] and Albee,[4, 5] are still vivid in our minds. The recent work of Kleinberg[79, 80] is a further valuable contribution in this field. We cannot conclude this short résumé of the history of scoliosis without making reference to the work of Farkas[38] and his newest contribution to our knowledge of scoliosis. It is easily the most scientific and painstaking contribution of modern times. To his views on the mechanics and pathogenesis of scoliosis ample reference will be made later in this chapter.

II. THE MECHANICS OF THE NORMAL SPINE

One cannot enter into a discussion of mechanical problems involved in scoliosis unless the mechanical principles of the normal spine are first made clear. No sane judgment upon important points of management of scoliosis can be arrived at without knowledge of mechanical as well as pathologic essentials, and though a theoretic discussion of this kind requires possibly an inconvenient amount of concentration, there is, unfortunately, no short cut to practical application.

In the fact that disalignment, in most instances, develops from originally normal and symmetrical positions, there is added reason why we should give first consideration to the mechanics of the normal spine. One must, however, make two qualifications to the statement that scoliosos develops from normal and symmetrical positions. First, the so-called congenital scoliosis cannot be strictly analyzed from the viewpoint of normal mechanics, since in these cases, the spine, at no time, has been under normal static and dynamic conditions. Secondly, certain types of scoliosis develop from positions of relaxation at a time when the definite configuration of the weight-bearing spine has not yet become established. This is the case in some rachitic spines, which assume an anteroposterior curvature before the static functions of the body, namely, standing and walking, have made their appearance, so that they, likewise, have not been subject to conditions of normal strain and stress. But aside from these exceptions which cover a comparatively small range of cases, a consideration of the normal mechanical and anatomic background will apply to the greatest part of the scoliotic material at hand.

1. Intrinsic Equilibrium

The normal spine does not represent a straight rod, but has three anteroposterior curves: one forward in the cervical, one backward in the dorsal, and one again forward in the lumbar region (Plate XVII, 1). Were the spine a straight rod, the line of gravity could pass through the center of the bodies, the pelvis and on to the ground, and an automatic equilibrium could thereby be established without any muscular effort whatsoever. As it is, however, the line of gravity must intersect the spine at certain levels. These are the cervicodorsal, the dorsolumbar, and the lumbodorsal junctions. Only in these three regions does the line of gravity fall within the substance of the body; at all other points the line of gravity falls outside the centers or outside the substance of the vertebral body as a whole. This means that gravity not only creates pressure stresses upon the vertebrae, but also tension or bending stresses, which tend to accentuate the already existing curves. If the equilibrium of the spine as a curved rod is now to be maintained these tension stresses must be duly equalized by special anatomic arrangement. In the dorsal spine where the line of gravity passes in front of the centers of the bodies, the tendency of the spine is to go into forward flexion under the superincumbent weight. This tendency is counteracted by ligamentous structures such as the posterior longitudinal ligament, or the interspinous ligaments, ligamenta flava, which are built to resist this tendency of forward flexion. The situation in the lumbar spine where there is normally a lordosis, is such, that body weight would tend to accentuate this curve, but, here also, the tendency is resisted by the tension of the anterior longitudinal ligament, the intervertebral discs, etc. (Plate XVII, 2, 3).

2. Distribution Mechanism of Stresses

Whatever the developmental reason may be for the existence of these anteroposterior curves, from a dynamic point of view, it has a deep meaning. They put the spine in the condition of a spring to counteract the innumerable jars and concussions to which it is subject. This is no small problem if we consider the countless jolts and jars created in running, jumping, riding: all sustained by the spine without the slightest disagreeable sensation. This is because there is in the spine a marvelous distribution mechanism for the strains and stresses by virtue of which they are deflected to the ligamentous apparatus, and thereby received and counteracted by tension stresses produced in the ligaments (Pusch[110]). If such stresses are felt as disagreeable sensations then something is amiss with the distribution mechanism of the spine. Instead of gravital stresses it is better to speak of the changes and variations of these forces, and we find that under normal conditions the spine is thoroughly fortified against these changes which are duly taken up by the resiliency of the ligamentous apparatus. Under pathologic conditions, however, we may find the spine unprotected against the fluctuations in gravital or dynamic stresses, and strains or even fracture may result. So we see that the spine is not a solid unit of bony segments but an elastic system kept in a perfect state of dynamic equilibrium in all positions that it assumes. If we want to go further into the study of the normal dynamics of the human spine, therefore, we must be conversant with all the tension stresses which are operative within its structures, those existing in the bone and those developed in the ligamentous apparatus as well.

3. Intrinsic Vertebral Structure

Those in the bone we may designate as the intrinsic architectural stresses of the vertebrae. According to the law of Wolff[156] expressing the adaptation of bone in form and texture to external physical stresses, such stresses must be represented implicitly in the trabecular arrangement of the vertebrae. Gallois and Japiot[49] made a study of these trabecular systems in the verte-

PLATE XVII

Fig. 1.—Anteroposterior mobility of spine. (After Virchow.)

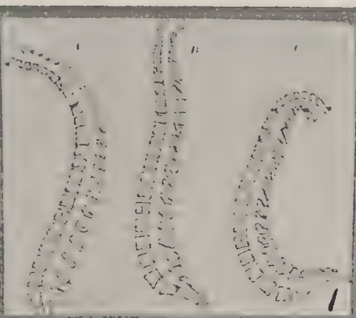
Fig. 2.—Ligamentous apparatus of vertebra. Tension and compression stresses. (After Braus.)

Fig. 3.—Costovertebral articulations. (After Braus.)

Fig. 4.—Horizontal trabecular systems. Line schema (after Gallois and Japiot).

Fig. 5.—Vertical trabecular systems. Line drawing (after Gallois and Japiot).

Fig. 6.—Plane and direction of intervertebral articulations. Note oblique frontal direction of dorsal articulations; sagittal direction of lumbar (as indicated by arrows).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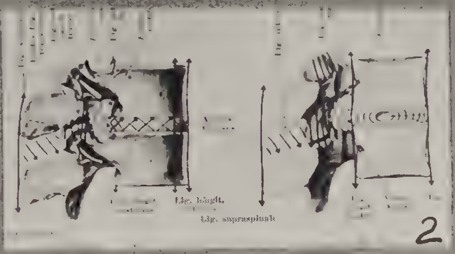

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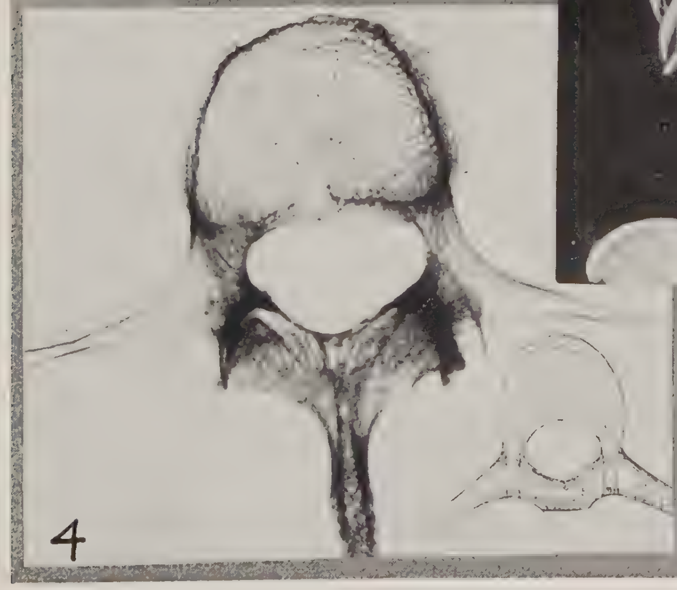
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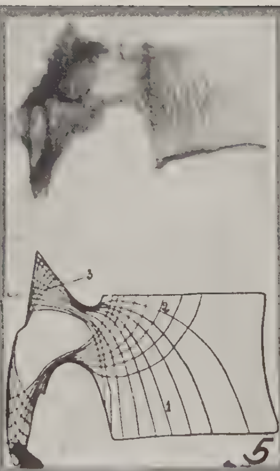

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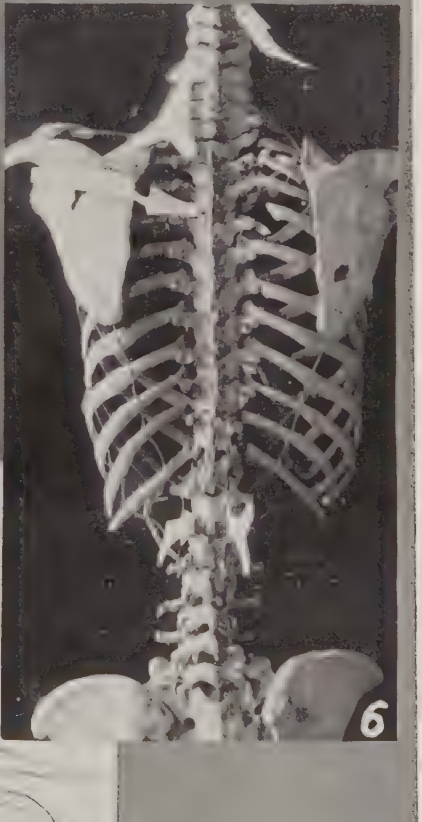
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PLATE XVII

brae, and came to the conclusion that the internal structure of the vertebral bodies is arranged in perfect accord with its precise function. The trabecular system is just as truly indicative of the stresses sustained by the vertebrae and as truly a mathematical expression of it as is the trabecular system found by Culman and Wolff in the upper end of the femur.

In the vertebrae we may distinguish three different and distinctive systems, namely, the vertical or principal, on one hand, and the oblique and horizontal, or accessory systems, on the other. The vertical trabeculae are arranged throughout the entire vertebral bodies running from one vertebra to the other as though there were no interruptions by the intervertebral discs. This system commences with the odontoid process and reaches into the sacrum. This is the trabecular system which gives the entire spine its mechanical unity (Plate XVII, 4, 5).

Of the accessory systems, the oblique one runs in four divisions from the right upper articular process to the left portion of the vertebral body, and vice versa on the left side, i.e., the superior oblique system; the other oblique system runs from the right lower articular process forward to the left upper portion of the body, and vice versa on the other side: the lower oblique system.

The horizontal trabecular system comes from the transverse and spinous processes, traverses the pedicle, and loses itself within the body of the vertebra. All these systems demonstrate the remarkable unity and rationality in the architecture of the vertebrae. Translated into mechanical terms we may say: that the vertebrae manifests a more passive function in the body, and a more active function in its processes. The body principally sustains pressure, while the apophyses or processes are levers for the application of muscle force (Plate XVII, 4, 5).

4. Articulations Between Vertebrae. Costal Articulations

The next point to consider is that the spine is not a solid mechanical system but consists of a number of articulated segments. The articulations between the vertebral bodies are represented by the intervertebral discs. The articulations between the processes of the posterior column are represented by the intervertebral articulations. Thirdly, the articulations between the spine and thorax are represented by the costovertebral articulations.

Now, the arrangement, the direction, and the range of these articulations have a great deal to do with the normal mobility of the spine, which, of course, would be impossible without articulations. On the other hand, the stability of the spine must needs suffer by the interpolation of so many articulations. We recognize now, that this prop of the human body, the spine, is not a straight rod but a curved one; and in addition, it is segmented by numerous articulations which make the problem of balance and equilibrium still more difficult and complex. Yet this very ability of the spine to maintain equilibrium, is the earmark of its physiologic integrity. The spine must be able, at any moment, to maintain itself in a perfectly balanced position; moreover, it must also be able to relinquish the position of actual symmetry and to assume, in its articulations, any asymmetrical position within its range of motion; and thirdly, it must be able to revert from any such asymmetrical position again to the position of perfect symmetry with the utmost freedom and precision. The ability of the spine to revert at will to perfect anatomic symmetry is the salient characteristic of normal function. How can, under these adverse conditions of multiple segmentation, a spine maintain its equilibrium?

5. Equilibrium of the Spine at Rest

Let us first consider the equilibrium of the spine at rest. We have described the spine as a curved rod, and have mentioned the ''S''-shaped undulation of the spine as a means to give it a certain buoyancy and elasticity. This condition also, is, in itself, a safeguard against deformation in lateral direction. Anyone can convince himself of this fact, who tries to produce a lateral bend in a curved rod. Even a small increase in an anteroposterior curve, especially of forward flexion, is sufficient to secure the spine against lateral deviation; that is to say, the spine is better stabilized against such a deformity by virtue of its anteroposterior curve. So we see that the kyphosis is a condition which counteracts and not facilitates, lateral curvature. We see, further, that the normally curved spine, in spite of its segmentation and contrary to what we would possibly expect, has a considerable degree of automatic equilibrium, so that it takes only a small amount of external muscular force to maintain it.

If the spine is removed from the body and dissected free from all muscles, so that only the bones and ligaments remain, it still represents a rather firm column. It is rather rigid, not only in erect position, but also shows normal limitations of flexibility (Adams[2, 3]). The ease with which ligaments and muscles hold the spine in erect position with a comparatively small expenditure of energy, is quite in contrast with the amount of muscle power necessary to hold the equilibrium in the lower limbs. After a long protracted illness one often sees that patients are able to sit up straight long before they are able to stand, because of the much lesser degree of muscle power necessary for the body to maintain its upright position in sitting as compared with the muscle requirements necessary for stabilization of the lower extremities. From these sporadic and rather dissociated facts one learns that there must be at work a remarkable arrangement by which the equlibrium of the normal spine can be maintained with the least possible effort and without interference with its mobility; an arrangement in which all structures of the spine, the ligaments, the discs, and the articulations, take their appointed share.

6. Passive Equilibrium of the Spine

How is this passive equilibrium of the spine normally maintained, and what part do the different structures play in maintaining it?

a. The Ligaments.—The ligaments uniting the arches and spinous processes, the ligamenta flava, the intertransversaria, and ligamenta spinosa, as well as the longitudinal ligaments, are, in upright position, under tension stresses. That is, they are fitted in the whole mechanical system under elastic stress. If one separates the entire column of the arches from the column of the bodies, the length of the column of the arches at once shrinks by 14 per cent and the tension of the interspinous ligaments and ligamenta flava becomes released. These tension stresses of the ligaments press the vertebrae firmly against each other, thereby contributing to the solidity of the spine as a whole. The longitudinal ligaments of the spine, both anterior and posterior, are mainly taxed for tension stress, the anterior becoming taut in backward extension, the posterior in forward flexion (Plate XVII, 2, 3).

b. The Rôle of the Articulations Between the Vertebral Bodies. The Intervertebral Discs.—These are also fitted into the system under stress; though not under tension, but under pressure stresses; that is to say, the weight of the bodies flattens the intervertebral discs, and the discs act as elastic buffers between the bodies of the vertebrae, changing considerably in shape with the position of the neighboring vertebrae, becoming narrow at the concavity and wider at the convexity of the curve. Though not a true articulation, the discs allow freely the tipping movement between the adjoining surfaces of the vertebral bodies. This can only be, because the discs are elastic, and the nucleus pulposus in the center is able to shift its position backward and forward, right to left, as the spine moves in flexion-extension, or in side bending. If we compare the mechanical effect of the intervertebral discs with that of the ligamentous structures of the arches and spinous processes we find that the discs are under pressure and try to separate the vertebral bodies, while the spinous ligaments and ligamenta flava between the arches are under tension and try to pull the posterior arches together. So, we have two contending forces, and between these an equilibrium is formed which is expressed in the normal physiologic curve of the spine. Intervertebral discs and spinal ligaments, therefore, harbor considerable intrinsic elastic forces which are painstakingly equilibrated. They impart to the spine an enormous amount of resiliency and resistance. No wonder that the spine, under the protection of these elastic structures, powerfully resists deforming influence of the force of gravity, and that it can maintain its equilibrium with so little muscular effort.

c. The Intervertebral Articulations.—These are represented by the articular facets of the articular processes. They allow of motion in diverse planes and about diverse axes. The range of these motions varies according to the section of the spine. The motion executed in the vertebral articulation is always a gliding and never a hinge motion, because the center of motion lies outside the articular facets.

The type and degree of mobility at different levels is of the greatest importance for the maintenance of the equilibrium of the spine. It is also a great factor in determining the site and shape of the lateral curvature, which represents a break in this normal equilibrium (Plate XVII, 6).

As we now consider the spine with all its articulated segments as a whole, it represents an intricate, many-linked mechanical system, laboriously set up and maintained in a state of equilibrium. This state of equilibrium would be necessarily a very precarious and labile one were it not for the stabilizing actions of the ligamentous apparatus and the musculature.

A spine deprived of all its muscular and ligamentous checks, if left to itself would automatically slump into positions of disalignment. Is this slump a fortuitous, haphazard one?

No, because it is determined by the type and degree of motion possible in the intervertebral articulations, and it is so fully guided by these that we may say that the collapsing spine slumps along a compulsory and obligatory route. For instance, in the dorsal spine this slump would present principally forward flexion and rotation since these are the two most favored types of motion in the dorsal articulations. In the lumbar spine, on the other hand, lateral motion is favored and expresses itself in the lateral body tilt.

d. The Costovertebral Articulations.—These consist of the articulations between the heads of the ribs and vertebral bodies on one side, and the tubercles of the ribs and the transverse processes on the other. For mechanical purposes we consider both joints as one unit (Plate XVII, 3). These articulations are amply reinforced by ligaments extending both between the heads of the ribs and the vertebral bodies, and between the tubercles and the articulating surfaces of the transverse processes. The combined axis of these two articulations runs from behind and outward to forward and inward, in an oblique direction, which in the upper ribs approaches more the frontal plane, and in a lower more a sagittal plane. Because of this arrangement the upper ribs in elevation swing more forward, while the lower swing more outward, a very important point in the mechanism of breathing. In all these movements, a portion of the ligaments which reinforce the joints becomes taut, and another portion is relaxed; thereby a certain amount of energy is stored against the time when the opposite movement begins. In addition to this the upper seven ribs are directly joined with the sternum by means of the interposed cartilaginous sections. In their continuous respiratory play, the ribs with their cartilaginous portion constantly change their shape, becoming longer and flatter during inspiration, and shorter and more curved during expiration. As they elongate themselves they drive before them the sternum like a driving rod, up and down, forward and backward. In addition to this the angle between the cartilaginous and bony portions and between cartilage and sternum also becomes greater and smaller periodically. All this evokes within the semielastic bodies a great many intrinsic elastic stresses, which, of necessity, project themselves backward toward the costovertebral articulations. The result is that the vertebral bodies, in the normal spine, are clamped between the vertebral end of the ribs, as in a vise. This is an important point to remember because it will serve us later to explain the manner in which the spine collapses in certain forms of scoliosis.

Eliminating all muscle action, we find the spine in a state of equilibrium furnished by a multitude of forces which are derived from elastic stresses coming from bone, cartilage, and ligaments. Between the spinal column behind and the sternum in front, the ribs are bent into position against their elastic resistance very much like a rim or hoop would be bent over a wheel or barrel. If one further considers that a portion of the ligaments of the costovertebral articulations is always in a state of tension, and if one adds to this the already described elastic resistance within the ribs and their cartilages, then one gets an idea of the enormous amount of energy which is stored up in the thoracic cage. Some of it becomes active in respiratory excursion by resisting, or aiding, as it were, muscular activity in respiration; and some of it, again, is converted into the vise-like grip with which the posterior costal ends hold onto the vertebral column. It is the latter portion of the elastic forces in which we are particularly interested, because, as mentioned before, it represents an important factor in the stability of the spine. The anterior portions of the ribs which have greater pliability, adapt themselves more easily to their positions, but with the elasticity decreasing from forward to backward, the pressure effect of the ribs manifests itself, more and more, in supporting and stabilizing the vertebral column.

The intrinsic stresses within the thoracic cage also reveal themselves by the diastasis of the sternum when cut transversely, and by the gaping of the ribs when these are severed on both sides of the thorax.

e. The Effect of Muscles upon the Equilibrium of the Spine.—The older anatomists recognized only one respiratory muscle, the diaphragm. Borelli[18] thought respiration possible without action of the intercostals. It was Duchenne,[34] who noted in animal experiments that as the diaphragm contracts, the ribs to which it is inserted, are, in the eventrated animal, drawn in, when the diaphragm is no longer contiguous and is no longer in relation with the abdominal viscera. In the noneventrated animal the base of the thorax widens out by contracture of the diaphragm. Here is the keystone of the respiratory equilibrium of the thorax. With the lower costal margin well immobilized by the abdominal muscles, the contraction of the diaphragm is normally not followed by an inward retraction of the lower thoracic cage, but by a widening of it, and by an elevation of the chest as a whole. This point, also, is of great importance for the understanding of the mechanics of scoliosis.

In an insufficient respiratory excursion, and with slanting ribs, relaxed abdomen and visceroptotic tendency, the dorsal spine instead of being supported by the clasp of the vertebral ends of the ribs follows the downward drag of the latter, so that, with the relaxation of the costovertebral junction a good deal of the natural stability of the spine is lost.

In the later discussion of rachitic and other forms of scoliosis, occasion will be offered to return to this element of the costovertebral relaxation as an important factor in the pathogenesis of certain forms of scoliosis. As far as the relation of the respiratory equilibrium to the muscles of the back is concerned, it can be stated that the sacrolumbaris as well as the longissimus dorsi, are the principal extensors of the back which aid in the respiration, and they have no appreciable rotatory action (Duchenne[34]).

The thoracic balance again depends upon the inclination of the pelvis, and the latter again upon the equilibrium between flexory and extensory groups of muscles. If there is paralysis or weakness of the flexors of the thigh upon the pelvis, the latter decreases in its inclination, while in paralysis of the extensors it becomes increased. In the latter instance the normal lordosis of the spine is increased, and the trunk correspondingly thrown backward, so that the line of gravity falls behind the sacrum. These factors become of great importance for deformities of the spine developing from paralytic conditions.

III. THE DYNAMICS OF THE NORMAL SPINE

1. Distribution of Motion

We must now consider the normal spine in motion. It has been indicated that the natural mobility of the normal spine is unevenly distributed, causing some sections of the spine to be more suitable for certain types of motion than others. Anteroposterior motion, or flexion-extension, is best developed in the cervical section and much less in the dorsal; backward extension in the dorsal spine is almost nil; and forward flexion is much greater in the upper portion of the dorsal segment than in the lower (Plate XVII, 1). Pure lateral motion is well represented in the cervical section. In the dorsal spine it has a value slightly larger than that of the cervical, but here, again, this type of mobility is more concentrated in the lower portion of the dorsal spine. In the lumbar spine again, from the 1st lumbar to the sacrum, the amplitude of lateral motion is not over 40 degrees on each side (Plate XVIII, 1). Rotation decreases constantly from the odontoid process to the sacrum; it is well developed in the cervical spine. It is also the principal motion of the dorsal spine where the amplitude is variously estimated between 80 and 90 degrees. In the lumbar spine, however, rotatory motion is very limited, amounting to only a few degrees on each side (Strasser,[147] Fick[40]).

2. Combination of Motion

Of greater interest for the mechanics of scoliosis are the combinations of motion, especially that of lateral and rotatory motion.

Lovett,[94] in his experiments on cadavers and on human models, found that all side bending, both in the cadaver and in the model, is automatically combined with rotation. He further found that flexion of the whole spine in lateral bending was associated with rotation to the convex side, that is to say, on the side of the convexity of the lateral curve the thoracic wall rotates backward; this is especially characteristic of the dorsal region. In hyperextension,

PLATE XVIII

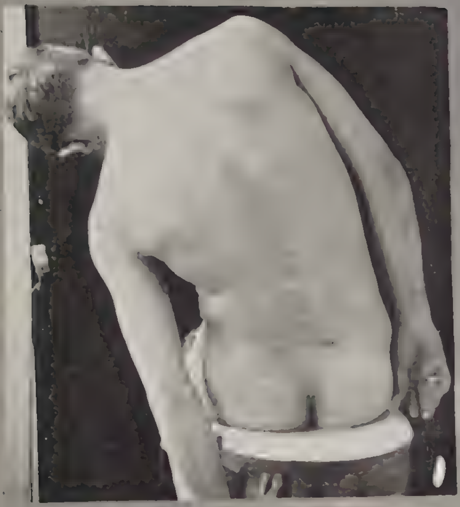
Fig. 1.—Lateral mobility of normal spine.

Fig. 2.—Intrasegmental (collapse) type.

Fig. 3.—Intersegmental (inclination) type. Pathologic specimen.

Fig. 4.—Wedged vertebrae. Detail of specimen in Fig. 3.

Fig. 5.—Detail. An oblique vertebra. Parallelogram shape.



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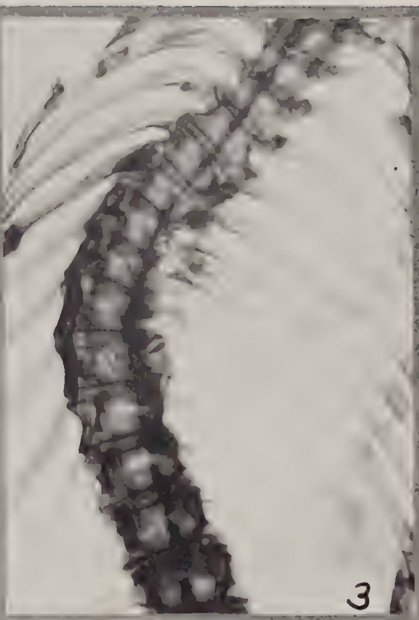

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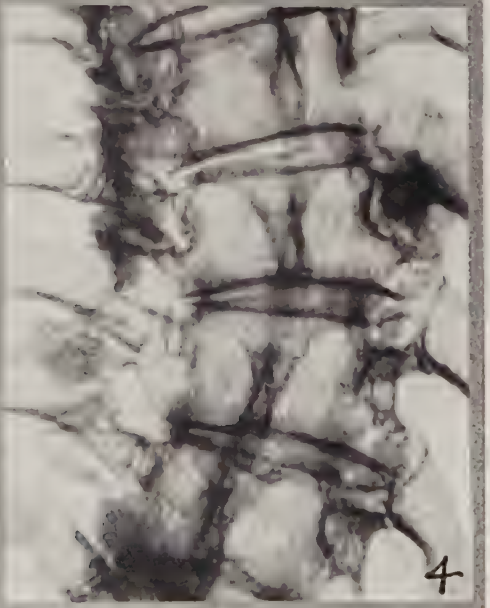

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PLATE XVIII

however, he found side bending associated with concave side rotation. He further found that forward flexion diminishes lateral mobility and rotation in the lumbar region, and that extreme flexion of the spine in this region locks it both to lateral bending and rotation. In the dorsal region, however, he found that it was hyperextension which diminished lateral mobility and rotation, and in extreme hyperextension the dorsal region became locked, both against lateral bending and rotation. Hence, in positions opposed to the natural anteroposterior curve, that is, in extension of the kyphotic dorsal section, and in flexion of the lordotic lumbar section, a check is set up against lateral motion and rotation. Lovett also found that in the dorsal spine rotation occurs easier than lateral bending, which is quite obvious since rotation is the principal and freest motion of this section. In the lumbar spine, however, lateral bending comes easier than rotation, and this again is easily understood since rotation is almost abolished in this section. It must be realized that the dorsal spine has a natural propensity for the combination movement of side bending and rotation to the convex side.

3. Concave Side Rotation

A good deal has been made of the question of the so-called concave side rotation, that is, a rotation toward the concavity of the curve when the spine bends to the side (Vulpius[153]). Lovett finds this to occur only when the patient bends to the side in a hyperextended position. Other observers, such as Werndorff and Reiner,[115] dispute the existence of the so-called concave side rotation. Schulthess arrives at the same conclusion as Lovett. The weight of evidence points to the fact that the arrangement of the dorsal articulations is such as to cause a propensity to slump into convex side rotation and lateral bending when the spine is left to its own inertia. It means that, without any muscle power, and left solely to the force of gravity, the dorsal spine would, on a compulsory route dictated by the arrangement of the intervertebral articulations, proceed to slide in this manner. So, we may say, that concave side rotation is not the expression of a natural tendency, but must be the result of some active muscular effort which holds the spine in a position opposite to that which it would assume by its natural inertia. This is of clinical importance. If we see a thorax rotated to the concave side, we know that it is due to physiologic or active muscular contraction. A spine committed to convex side rotation, however, appears to have lost voluntary muscle control and with it the faculty to revert of its own power to symmetrical position. The same observation on the correlation between bending and rotation was made by Feiss[39] and later by Abbott[1] and Frey.[46] More and more evidence is being brought forth to show that the convex side rotation is the natural one to accompany side bending, whereas the concave side rotation is the exception, peculiar only to initial stages. It is probably entirely physiologic and evidence of still existing voluntary muscle control.

IV. MECHANICS AND DYNAMICS OF SCOLIOSIS

1. Loss of Normal Equilibrium

Under certain conditions the normal equilibrium of the spine becomes destroyed. The spine, no longer under active muscle control, is, through the effect of weight-bearing and other forces, given over to deformity. In the ability of the spine to revert to symmetry at will from all asymmetrical positions with promptness and precision lies the characteristic earmark of the normal spine. The inability to do so makes the spine abnormal. The normal spine can, at any point within its range of motion, establish an active equilibrium, and can maintain this position at will as long as necessary, and can return to the position of perfect symmetry again, whenever it is desired.

It is entirely different with a spine undergoing deformation. Here, the departure from the absolute symmetrical position is involuntary; it is a progressive process, only halted by the resistance offered by the tissues, bones, ligaments, or muscles. These resistances arise from intrinsic stresses which develop within these structures. When these resistances finally force a halt in the progress of the deformity, the resulting position is not in a state of active equilibrium, but in one of passive equilibrium, since the arrest of motion of the spine is brought about entirely by the passive resistance in the stretched ligaments, in the blockage of the structures, etc. Naturally it depends upon the degree of plasticity of the spine whether such a natural arrest in the deformation will occur early or late, at the beginning, or at an advanced stage of the deformity. While the normal spine offers ample resistance to deforming forces to escape deformation under normal conditions, the abnormal spine is one that has become so loose and so plastic, in other words, so poor in resistance to external forces, that it is forced into deformity. The causes which underlie this lowering of the natural resistance of the spine, are also the ultimate reasons for the deformity. The external forces such as weight-bearing or dynamic stresses which immediately produce a deformity are not the real causes. These forces are active on all spines but few only react to this by going into deformity. For the real causes we must, therefore, look to inherent, systemic, or other changes in the spine itself.

2. Mechanical Forms of Deformity

From the manner in which the spine assumes its lateral curvature, two types may be distinguished. In one, the deviation occurs more or less around one point, and the whole superincumbent section rotates about it. This is, as Feiss[39] pointed out, produced by segmental motion; that is, the segment of the spine moves as a whole about a definite turning point (Plate XVIII, 3). In the other type the lateral bend is produced by collapse of the spine in which all vertebrae within the involved sections undergo a translatory or sideways movement, the one at the apex of the curve moving farther sideways than the others (Plate XVIII, 2). This distinction is of great clinical significance.

Some types of scoliosis are produced primarily by side bending, inclinatory; one section inclining over the other; other types are produced by this parallel or side shifting of the vertebrae (Farkas[38]). Peckham[108] as early as 1916 pointed out this fact of scoliosis being formed by collapse of a certain section of the spine in which the vertebrae are crowded "off to one side," distinguishing it from the angular bending or deflection in the other or so-called inclinatory type of scoliotic deformity.

As one studies the x-ray pictures of different types of scoliosis one will indeed see in one instance a segmental movement of one section of the spine against the other, the upper section primarily moving as a whole (Plate XVIII, 3); in another instance, one notices a short arc curve in which it appears that all vertebrae have entered in the parallel or sideways motion (Plate XVIII, 2). In the first instance we speak of a segmental, and in the second of an intrasegmental motion. In the first, one section of the spine moves as a whole against the other, and in the second the section of the spine collapses as would a spring, the vertebral bodies deviating sideways in a horizontal plane. Generally speaking, the segmental motion is the type initiated by muscle action—this is called the inclinatory type of deviation. The intrasegmental curve where all the vertebrae undergo a horizontal translatory, or sideways shift, is not produced by muscle action since no muscle can shift a vertebral body in horizontal direction. It is produced by the passive collapse of the spine under the superincumbent weight. Farkas[38] pointed out that the immediate cause of this translatory or intrasegmental movement of the vertebral bodies lies in relaxation of the costovertebral junctions.

This division of types, however, applies only to the primary manner of deviation. In both types, an intrasegmental, sideways shifting, or an inclinatory deformity may become superimposed upon the original deviation in the course of the later development of the curve. So we see that scoliosis shows no uniformity of development; it is, primarily, either an inclination deformity, as in the so-called physiologic or paralytic scoliosis, or a collapse deformity as in the rachitic scoliosis, but in the later course, both types are bound to enter into the formation of the curve.

The question now arises, how does the individual vertebra react to these types of deformation?

The characteristic formation of the inclinatory type is the wedge vertebra (Plate XVIII, 3, 4); the characteristic formation of the collapse type is the so-called oblique vertebra (Plate XVIII, 5). The difference between these two types is easily stated: in the inclination type the angulation is more or less defined in the intersection between the two segments, and the motion really occurs in the articulation between the upper and lower segments which thereby change their relative position to each other. At the point of intersection the respective vertebrae become wedge-shaped or depressed at the side of the concavity of the curve. In the collapse type all vertebrae take part in the parallel or translatory motion; the mechanical effect of it is that the vertebrae appear parallelogram-shaped or oblique.

The segmental or inclinatory type is due to muscle action, and, up to a certain stage, it can be corrected and controlled by muscle action. As long as this is possible we speak of a physiologic stage of scoliosis. After a certain length of time, however, the scoliosis enters the contractural stage in which the voluntary correction of the deformity is no longer possible, and then we speak of contractural or structural scoliosis. In the intrasegmental or collapse type, the lateral bend is a symptom of collapse in which all vertebrae within the involved section undergo the already described translatory movement to the side. The vertebra at the apex of the curve undergoes the greatest amount of lateral shift, and shows the greatest degree of deformity. The result of the collapse is a settling down of the spine under the body weight, whereas, in the inclinatory type one portion of the spine, as a whole, inclines against the other. Inclinatory movement of the spine, however, becomes later implanted upon the collapse deformity, whether the spine tries to righten itself by compensation, or self-correction, or whether the deformity proceeds to natural increase.

3. Thoracic Cage in Collapse Type of Scoliosis

To make the collapse type possible it is necessary that there be a relaxation of the spine at the costovertebral junctions. Only when the supporting influence of the thorax as a whole relaxes, and when the natural anchorage of the vertebral bodies with the ribs, which is so essential in the normal automatic equilibrium of the thorax, has experienced a pathologic change, can such a collapse type of deformity occur. This is a typical type of deformity in rickets, where the ribs are less firmly anchored than in the normal, are soft and pliable and lose their hold upon the vertebral bodies. In the lumbar spine where there is no such anchorage of the ribs, their place is taken by the sagittally placed articulations, and these usually take care of the anchorage of vertebra to vertebra. If these articulations relax and assume a pathologic degree of pliability, then the lumbar spine collapses in a similar manner as does the dorsal spine.

V. PATHOGENESIS OF SCOLIOSIS

1. "Insufficiency of the Spine"

A great many theories have been advanced on the causes of scoliosis. Schanz[128, 130] held that it is a result of a disproportion between weight-bearing forces and the natural functional ability of the spine to resist the influence of these forces. Since weight-bearing is a general factor applying to all cases and under all conditions, except in those cases which develop before the static functions of the body are established, it is clear that such an explanation, in its wide generality, cannot easily be challenged. It does not, however, go further in the explanation of the chain of events, because it does not enter into the causes which underlie this functional inferiority of the spine. It seems more to the point to investigate the conditions under which weight-bearing will produce scoliosis in certain individuals, when it obviously does not do so in the rest of mankind. Duchenne,[34] Roser, Volkmann,[152] and other older observers share this theory of functional inferiority, assuming, in a general way, a lowered resistance of the spine without, however, advancing further into the question of the more specific causes.

Why, in the majority of people, does the effect of weight-bearing remain innocuous, and the spine under complete muscular control, whereas in others under apparently the same external conditions, deformity develops? Is this deficiency of muscle control, or to use the term of Schanz,[128] this *vertebral insufficiency*, only a secondary factor, and if so, what organic change in the spine is behind it?

2. Attitudes, Muscular Fatigue

Recognition of such constitutional deficiencies, congenital or acquired, would seem the final step of investigation in the field of pathogenesis.

There are, first of all, a number of predisposing factors to be considered. Here belong the attitudinal positions such as might be encountered in certain occupations. They are assumed by Meyer,[97] Lovett,[94] Feiss,[39] Abbott,[1] to be the direct cause of scoliosis, at least of the so-called idiopathic or habitual form. As this explanation again only covers part of the cases, so it also satisfies only a part of the question as to the definite causes. Concerning attitudinal variations as basis for curvature, Schede,[132, 133] makes a distinction between position and attitudes of the spine which can be assumed at will, and so-called obligatory attitudes. The latter are prescoliotic attitudes representing relaxation or fatigue in two types: the total kyphosis in which the pelvis is tilted backward, and the round hollow back with increased inclination of the pelvis. From these fatigue attitudes, according to Schede, all those scolioses develop in which there is no primary, congenital, or pathologic variation, or any inherent constitutional defect such as in severe rachitic deformities. We have arrived, then, with Schede, at the point to consider inherent muscular weakness as the background of the deformity, leaving aside for the moment the question whether or not this inherent muscular weakness is not in itself secondary to some deeper inherent deficiency of the skeleton. But whether or not secondary to deeper skeletal deficiencies, it is evident that the scoliotic contractures developing from attitudes of fatigue are efforts to recover the equilibrium of the spine; they are diminished or disappear in horizontal position. For the so-called prescoliotic state, that is, a state in which only attudinal postural anomalies are present, before it comes to the true contractural scoliosis, these muscular insufficiencies are of great importance. They are essential in producing the round hollow, and the round back which are precursory stages of the left total scoliosis.

Another theory is that of Bouvier,[19] who believes that the original physiologic scoliosis leads to the development of lateral curvature. Under physiologic scoliosis he understands the normal lateral deviation of the spine which, under certain conditions, becomes accentuated to a true deformity. But again, we must ask, why should some cases react to these factors by scoliotic deformity when they are being tolerated without pathologic changes by the majority of spinal columns?

Another angle is projected into the problem by Jansen.[71] He points out the asymmetry of the diaphragm as a factor in the formation of scoliosis.

3. Constitutional Causes

Having approached the question of pathogenesis from the more general term of insufficiency, and advanced to the more specific conception of muscular weakness, we now turn our attention to the condition of the skeleton itself. Can an inherent constitutional change of the skeleton be established for a large group of scoliosis?

Schede maintains that in most cases the typical scolioses are rachitic, so far as the pathologic basis of the skeleton is concerned, but that they are all habitual in so far as they are produced from positions of relaxation. As we look for periods of increased plasticity of the spine, and lessened resistance against its deformation, it is significant that the three periods of increased growth of the spine, namely, the first and second years, the fifth to tenth years, and then the period of puberty, all coincide with frequent occurrence of deformities of the spine (Jansen[68, 69, 70]). The conclusion seems to be justified that muscle weakness alone is not sufficient to produce genuine true scoliosis in a large group of cases, that for the latter an independent disease, or change in the skeletal part of the spine, is necessary (Schede). Jansen points out that rickets is the answer of the growing organism to external influences of all kinds; according to him the rachitic organism makes three types of responses, corresponding to the particular period of rapid growth. In the first period (first to second year), we have the typical rachitic type with insufficiency of the musculature and the whole skeletal system. In the older child (three to five years), we have the genu valgum, the poor musculature, the rapid growing epiphyses, etc. The adolescent child's response is weak musculature, rapid growth and poor resistance of the skeleton. According to Schede this group represents the majority of cases in which scoliosis develops from attitudes of relaxation, either rachitic or the so-called habitual.

The radiologic examinations of Engelmann[35, 36] revealed two types of rickets: one exclusively epiphyseal, and one more diffused, or malacic. The latter is supposed to be the forerunner of severe rachitic scoliosis in younger children, while the former is productive of a later occurring so-called habitual scoliosis. There is no essential pathologic difference between the two forms except one of degree and time of appearance. The fact that in habitual scoliosis, deformities of the extremities are not found, is no argument against the conception of a rachitic origin of habitual scoliosis. In small children we have the picture of rickets, that is, rickets in the stricter sense, and during puberty we have the picture of so-called juvenile osteomalacia. Between these two there are all kinds of transitional forms. Substituting, then, for Schanz' term of lowered resistance, the somewhat more concrete one of rachitic preformation, it is interesting to note to how large a group of acquired scoliosis, not having any other definitely established origin, this form might logically apply. The question now becomes one of definition of rickets; applied in the larger sense of Schede and Jansen, the term is liable to lose its generally accepted pathologic identity.

For the early rachitic curve the connection between preexisting rickets and spinal deformity can be easily established. It is much more difficult to do so for the late appearing scoliosis. According to Fromme[47a] (1922) the rachitis tarda of the adolescent is the same condition as the rickets of small children. There is, according to most investigators, no congenital rickets, the earliest case (Schmorl[135]) being observed at the age of one and a half months. We draw the line between rickets of infants and rachitis tarda after the fourth year, the latter appearing in the tenth to fourteenth year, so that between four and ten there is another latent period. The manifestations of rachitis tarda occur during adolescence, that is, during a period of more intensive growth. Of interest for the pathogenesis of scoliosis is the finding (Schmorl) that rachitic changes of the ribs may occur even after the length growth of the long bones is concluded, the thorax growing in width even later, due to the independent growth of the ribs. We have persistence of cartilaginous ribs into middle age and beyond, and ossification at the bone cartilage line persists apparently beyond the growth period into adult life. All this creates difficulties in setting a lower time limit for late rickets, especially since some believe that the latter represents only a recrudescence of infantile rickets.

It is, furthermore, to be pointed out that a relationship between rickets and osteomalacia probably exists (Recklinghausen[112]), and infantile osteomalacia is likewise of greatest importance for the pathogenesis of weight-bearing deformities.

In the first years following the late war there was observed an enormous increase of infantile, as well as of late, rickets. Schmorl estimated the incidence of late rickets at 4 per cent of the population. In late rickets also disturbances of enchondrial ossification are observed in the ribs, in the same remissions and recurrences as seen in typical rickets. From these points of view it is not strange that many of the newer conceptions regarding habitual scoliosis lean toward the assumption of rickets, and Lange[86] classifies all severe scoliosis with so-called kyphoscoliotic deformity as rachitic. Disturbances in the enchondrial ossification of the spine itself was demonstrated by Schmorl. They appeared first at places which are the most exposed to weight-bearing stresses such as the lumbar spine. Pollarsson[109] found thickening and irregularities of the cartilage covering the upper and lower surfaces of the vertebral bodies. Microscopic investigations are urgently needed, although this much can be said, that of all permanent deformities of the spine which presuppose acquired anatomic changes, the only definite and surely established are those due to rickets and late rickets, conditions which have an extraordinary importance in the pathogenesis of scoliosis.

4. Congenital Deformities as Cause of Scoliosis

More concrete evidence of the effect of skeletal changes upon later developing deformities is established in the group of Congenital Scoliosis.

Investigations of Boehm[15, 16] and later Putti,[111] drew attention to certain congenital preformations pertaining to the vertebral body, the arches, the processes, the articulations, or the relations of the costal cage to the thorax in general. Especially the formation of the 5th lumbar vertebra has been studied with great interest. The effect of the anomalies of the 5th lumbar upon the formation of scoliosis has been established by the studies of Adams[2, 3] and others, though their importance as a scoliosis-producing factor is by no means entirely clear.

Congenital scoliosis may be divided, clinically, in one group observed at birth, and in another becoming manifest later (Mouchet and Roederer[99]). In the first group again, we may distinguish cases without preceding postural anomalies, and others which have postural anomalies in utero, and are frequently associated with suppression of vertebrae. The wedge-shaped bodies represent either a supernumerary fragment or part of a normal series. Supernumerary fragments are frequently found in the lumbar region between the 1st and 2nd lumbar vertebrae. Some of these types of congenital scoliosis are benign. If the seat of the supernumerary segment or anomaly is in the lower dorsal or lumbar spine there is less opportunity of establishing a compensatory curve below; but if these curves are rather angular and involve only one or two vertebrae, the neighboring structures can still accommodate themselves to a change in direction and effect compensation. In another type it is rather a unilateral compression of the normal vertebrae than a supernumerary segment which is responsible for the deformity. This type also presents itself in different variations; here the middorsal spine is often involved, and the scoliosis is situated much higher than in the former type, and therefore, the spine, as a rule, is able to maintain its equilibrium.

The principal bases of congenital scoliosis are variations of the vertebral bodies, either in number or form, or both (Boehm[14]).

According to Putti[111] these numerical and morphologic variations of the spine come into play purely or combined. To the combined type belong cases of sacralized lumbar vertebrae. The obliquity of the 5th lumbar vertebra has been given a great deal of attention as a possible cause for a later developing congenital scoliosis. But, in the face of the great frequency of such obliquity of the 5th lumbar, we must ask the question, "Why does the superincumbent spine so often retain its straight course and develop no deformity?"

It is evidently because even upon the favorable ground of the congenital anomaly, another superinducing factor is required to bring about a manifestation of the deformity.

5. The Prescoliotic Stage

This is the phase in which postural and attitudinal anomalies first begin to appear, and which definitely precede the first sign of the lateral deformity. The prescoliotic stage, therefore, signifies a clinical period of absolute latency when the pathogenetic conditions, such as congenital malformations, rickets, habitual posture, etc., are present, but when, as yet, no unmistakable sign of scoliosis has appeared. Recognition of this prescoliotic stage is of the greatest importance, because it is during this time, and not in the beginning stages of scoliosis itself, that the most effective work of scoliosis prophylaxis can be accomplished.

a. Congenital Scoliosis.—For the congenital scoliosis no real prescoliotic stage exists. Definite asymmetry of the spine is a congenital factor. But there is often a long period of latency, the spine remaining under muscular control in spite of its anatomic handicap. Clinically, the prescoliotic stage manifests itself in occasional temporary abandonment of symmetry, the assumption of asymmetric postures of short duration.

b. Habitual Scoliosis.—For the acquired scoliosis, however, a definite prescoliotic state exists, but it is difficult to determine its beginning. Here also it seems best to date it from the occasional and still controllable postural and attitudinal anomalies. The scoliosis itself begins with the assumption of habitual asymmetrical attitudes. A child, who persistently assumes asymmetrical positions from which it is becoming more and more difficult to arouse him, is already in a state of scoliosis, as he already experiences some difficulty in reverting voluntarily to a position of symmetry. It is the occasional anomalous attitude which sometimes is not even of the scoliotic type, which must be regarded as the precursor of scoliosis. We observe the child with poor erectors of the trunk; when sitting he inclines his body forward. Here we have a prescoliotic condition because this attitude predisposes the patient for the coming lateral deformity.

Let us first consider in detail the different attitudes assumed in the prescoliotic stage. Here belong the different positions of rest and relaxation, manifested in standing, sitting, lying, or walking. Up to recently it was believed that these asymmetries, especially those in sitting postures are being formed during the school years, and were spoken of as "school scoliosis," meaning by it attitudinal anomalies which later lead into true scoliotic changes. We know now that these attitudinal anomalies occur much earlier, usually in preschool years. The rapid growth during school years accentuates the tendency to faulty attitudes; it increases the opportunity for fatigue and muscle exhaustion. Faulty posture in writing, faulty attitude in standing, asymmetrical carrying of books, etc., are contributory factors; these are, however, not factors of the real prescoliotic stage, but are operative already during the development of the deformity.

The defect of gait also should be considered as a predisposing element though little attention has been paid to it. Farkas[38] lately has called attention to the fact that there exists an essential difference between the gait of the male and the female types, the pelvis in the female making much greater excursion in all planes, while the male pelvis is better stabilized.

Orthopsy, that is, the necessity of holding the head in the straight horizontal line of vision, also has its effect upon the assumption of asymmetrical attitudes. To this must be added asymmetrical attitudes caused by obliquity of the pelvis, a shorter leg, congenital dislocation of the hip, etc.

The normal spine is able to compensate for the pelvic tilt and the body is held erect. When the spine occasionally falls out of the erect posture, a prescoliotic stage exists; when the asymmetry becomes more and more habitual and is increasingly less controllable by muscles, a scoliosis exists.

c. Rachitic Prescoliotic Stage.—Of greatest clinical interest is the so-called rachitic prescoliotic stage. It starts as an anteroposterior curve in the lower dorsal spine, and is one of the early signs of spinal rickets, occurring at the time when the sitting attitude is assumed. Many of these curves are either actively straightened out by the subsequently developing musculature, or are compensated by developing a converse curve below. The round hollow rachitic back is an example of such a natural compensation. Occasionally, however, the musculature is too weak to effect such compensatory adjustment. According to Farkas in those cases the body automatically rotates around to counteract and check the forward flexion. In other words, the flexion deformity of the spine is arrested by a twisting motion which carries the curve from the sagittal into the frontal plane. This explains the fact that many of the rachitic curvatures of the spine seen in young children are preceded by anteroposterior curves, and in this conversion of the anteroposterior curve into a lateral curve by rotation of the body, an illustrative example is given of a definite prescoliotic stage. The child begins with a total kyphotic deformity which is his normal attitude as he learns to sit up. Rickets supervenes and the kyphotic curve becomes accentuated in the dorsolumbar region where the pressure is the greatest (Recklinghausen[112]). The dorsolumbar kyphosis persists after the child has begun to stand up and walk. This kyphosis is the remainder of the total kyphosis which was natural in the sitting child. When compensation of this kyphosis cannot be accomplished, the danger of forward flopping of the spine becomes increased, and then it is only by the rotatory twist of the body that the child enforces an upright position. If, on the other hand, he succeeds in compensating his anteroposterior curve by developing a round hollow back, then his spine is comparatively safe against lateral deviation. In the event of the compensation effort failing, the flat back results but this flat back is unsafe and very prone to develop into a lateral curvature of the spine. Engelmann's[35, 36] investigations showed that almost all spines with rigid kyphosis in the dorsolumbar region, show, in the flat dorsal segment, early slight scoliotic inflection.

d. Prescoliotic Stage of Paralytic Scoliosis.—Here we have a perfectly normal spine not inclined to any lateral deviation from any of the causes discussed before which is suddenly afflicted with a partial or complete loss of its musculature. In its mode of development it simulates the physiologic scoliosis; here also, habitual weakness of the muscles exists, and the paralytic scoliosis is likewise an inclination type, that is, deviation occurs from segment to segment about a point of inflection. This form of scoliosis develops so insidiously that it is difficult to speak of a prescoliotic stage. Often there is a long period of latency. Since the stability of the spine is suspected at once from other signs of paralysis, the slightest defects of muscular control can be detected early. When the scoliosis stage is once entered, the progress of the deformity is usually rapid.

e. **Empyematic Scoliosis.**—Of the prescoliotic stage of the empyematic scoliosis but little has been determined. It is also an inclination type of deformity, developing from the effect of an unequal intrathoracic pressure. In this condition it is also difficult to determine the point when active control of spinal movement becomes embarrassed. The prescoliotic stage is best dated back to the period of the original affliction.

VI. PATHOLOGIC ANATOMY

1. The Spine as a Whole

The principal feature in the pathology of scoliosis is that it is a combination of lateral deviation and longitudinal rotation (Plate XVIII, 3, 4). Both features are equally inherent and indispensable in making up the scoliotic deformity. As already stated, the lateral bend may primarily be the product of an inclination of one vertebra against the other in the intervertebral articulation (inclination type), or, it may be the result of spinal collapse, in which the bodies undergo a sideways shifting movement.

a. **Wedged and Oblique Vertebrae.**—Whatever the mechanism of the deformity, however, sooner or later the displacement goes beyond the normal range of motion and becomes combined with structural changes within the vertebra itself. The translatory displacement in horizontal direction leads to a trapeze-shaped obliquity of the body and with it, an alteration of its internal architecture (Plate XVIII, 5). In the same manner the inclination deformity leads to typical wedge formation of the vertebra and to corresponding structural changes (Plate XVIII, 4). Both types become later so closely interrelated that they can no longer be differentiated. At the intersection of two curves the vertebra changes the direction of its twist from the one corresponding to the upper curve to the one of the lower. The vertex of the curve always shows the highest degree of deformity. From the point of intersection of two curves toward the vertex, the vertebral body gradually loses the character of an oblique vertebra and assumes more the shape of a wedge vertebra. The intervertebral discs act very much in the same manner. They are similarly distorted: in oblique fashion in the neighborhood of the oblique vertebra, and in wedge shape in the neighborhood of the apex of the curve (Plate XVIII, 4).

b. The Rotatory Element of the Deformity.—Here, also, we must distinguish between a rotation which takes place in the intervertebral articulations, that is, from vertebra to vertebra, and a rotation within the structure of the vertebra itself. The latter, namely, the structural rotation within the vertebral body, is often designated as torsion of the vertebra (Plate XIX, 1).

In the dorsal section the rotatory movement of the spine is limited by the presence of the ribs, and in the lumbar section by the arrangement of the intervertebral articulations. It becomes greatly augmented, however, by the twisting of the bodies within their own structures, or torsion, and it is an essential part in all structural scoliosis.

2. The Vertebra

In examining the structural torsion of the vertebra we find not only the spiral twist within the vertebral bodies, but we find, also, that the neural arches with their transverse, articular, and spinous processes themselves are kinked against the vertebral bodies, the deflection being directed toward the concavity of the curve. This produces a distortion of the vertebral foramen; instead of oval it now becomes egg-shaped with the point toward the concave side. This kink also makes the pedicle on the concave side short and stubby, and the lateral processes of the concave side arrange themselves more in the frontal plane. On the convex side the pedicle and arch seem to be thinned out and long, and the transverse process on this side moves more backward into a sagittal plane (Plate XIX, 1). Under the effect of this textural torsion of the vertebra, its normal symmetry becomes destroyed. Whereas the normal vertebral body is bisected by a sagittal plane, the scoliotic vertebrae show a very marked deflection in relation to this plane. The convex side of the body seems enlarged, and the concave half of the vertebral body is contracted. It appears as though on the convex side the push of the costovertebral articulations would force the body into rotation, so that this side twists backward carrying the ribs with it, and forcing the latter into strong relief at the back. On the concave side the ribs are flat and it appears as though they were pulling the transverse process forward into a more frontal plane, thereby imparting to the body of the vertebra a rotation in a direction corresponding to the one into which it is pressed or pushed by the ribs of the convex side.

We see the anterior longitudinal ligament gliding off toward the concave side of the curve, pressing, thereby, against the anterior portions of the vertebral bodies. All these changes presuppose a certain elasticity of the ribs, without which no real structural torsion, either within the body or between bodies and pedicles, could take place.

The inner architecture of the scoliotic vertebrae is likewise thoroughly disturbed. The normal trabecular systems become twisted and spiral-shaped, and these changes again are most pronounced at the apex, and least at the intersection of two curves. It is here where the spiral twist changes from one direction into the opposite.

PLATE XIX

Fig. 1.—Torsion of the vertebra. Note asymmetry of spinous process.

Fig. 2.—Note rotation of bodies and deflection of spinous processes to concave side of scoliotic curve.

Fig. 3.—Short transverse process on concave side. Wedging of body.

Fig. 4.—Stubby and thick laminae and pedicles on concave side. Concave transverse process is more frontal. Convex is more sagittal. Note rotation of body convexly.

Fig. 5.—Flat and elongated rib (left). "Buckling" convex rib (right). Spinous process deviated to concave side of curve.

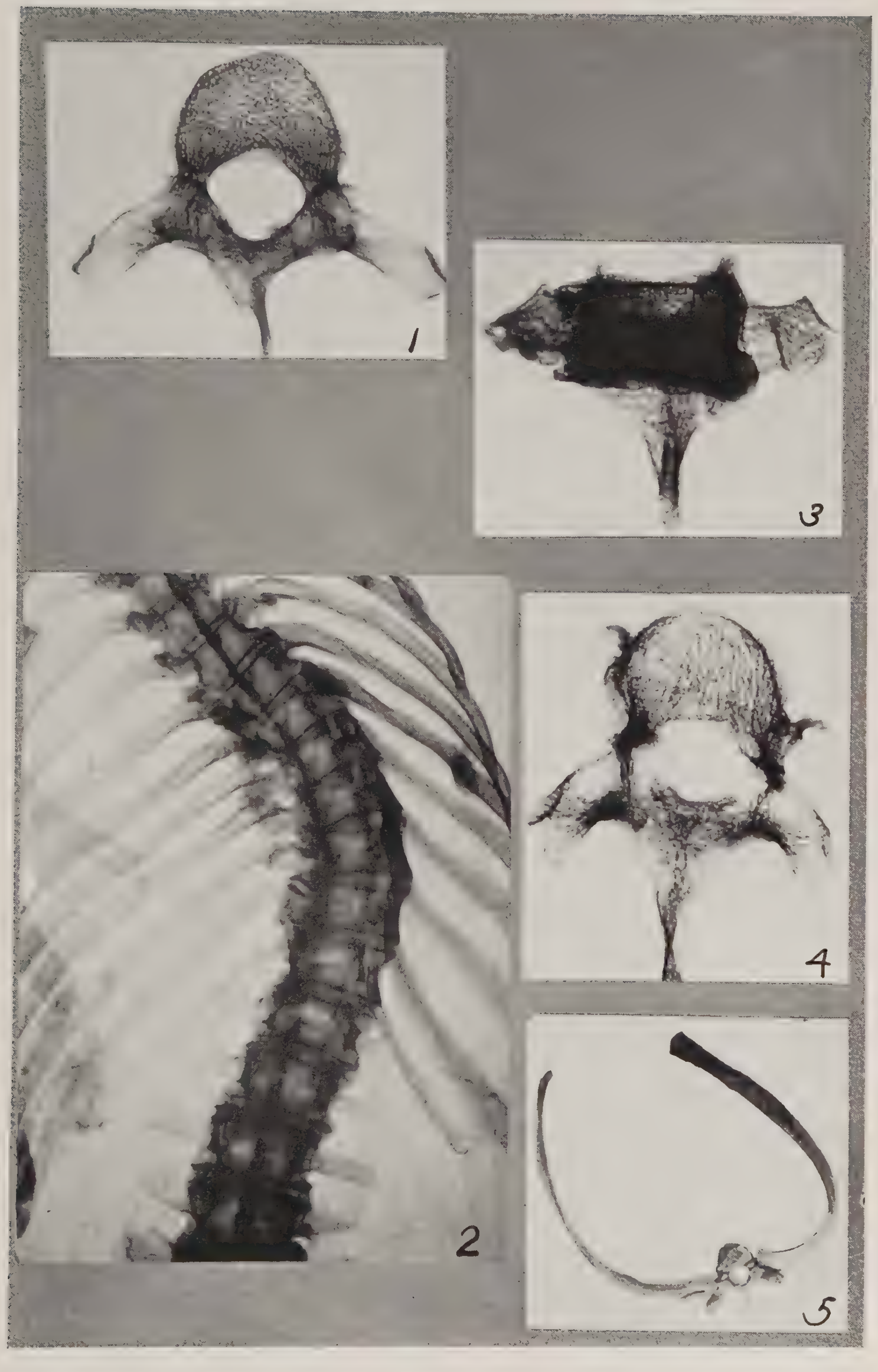


PLATE XIX

3. The Spinous Processes

As the pedicles and neural arches are kinked against the bodies of the vertebra toward the concave side, the spinous processes naturally follow. A line laid through the vertebral bodies forms with one through the middle of the vertebral arches, an angle opening toward the concave side. The spinous processes, moreover, are so pliable, and also so intimately connected with the ligamentous structures, that they become independently deflected toward the concave side, even more so than the pedicles (Plate XIX, 2). With all this deflection they become rather unreliable as an indicator of the degree of the curve; the arc described by the spinous processes is very much flatter than the one described by the centers of the vertebral bodies, owing to the fact that the tips of the processes are strongly deflected toward the concave side.

4. The Transverse Processes

The transverse or lateral processes follow the deflection of the neural arches and pedicles. On the concave side they become aligned in a more frontal, and on the convex side, in a more sagittal plane. On the convex side the transverse process appears longer, and on the concave side shorter and heavier (Plate XIX, 3). On the convex side it is deflected cranially or upward, on the concave side more caudally or downward, in keeping with the fact that the ribs on the convex side are elevated and those on the concave side are depressed.

5. The Laminae and Pedicles

In harmony with the angulation that exists between the neural arches and the bodies of the vertebrae we see also the laminae and pedicles directed in a more frontal plane on the concave side, and more in a sagittal plane on the convex side. The laminae and pedicles, likewise, appear thinned out on the convex side and stubby and thickened on the concave side (Plate XIX, 4).

6. The Ribs

The influence of the ribs upon the mechanism of the deformation is so fundamental that a more detailed description of the anatomic situation must be given.

On the convex side the rib is rolled up against the vertebral body and the transverse process; on the concave side it is seemingly pulled away from it, and appears straight and flattened. One gains the impression that the curled up convex side rib presses against the transverse process on its side, while the flat concave side rib seems to exert a tug or pull upon its transverse process (Plate XIX, 5).

So far we have only considered that the rib simply followed in its deformation the lead of the twisted and rotated vertebral body. But, as Feiss has pointed out, the ribs have a deformity of their own which is independent of the one imparted to them by the rotation of the spine. They, therefore, play in scoliosis both an active and a passive part. The active part is expressed in their effect upon the deformity of the transverse process and arches. The rib, taking part in the rotation movement of the vertebrae exerts a considerable and increasing degree of pressure upon the convex side transverse process against which it appears coiled up. This forces the transverse process upward and backward, but not without a great deal of counterpressure which produces additional deformation of the posterior end of the rib. The result is that peculiar kink between the vertebral bodies and pedicles by which the latter, being more plastic than the bodies, are buckled back toward the side of the concavity.

The rib on the concave side may be said to play a more passive rôle. With the rotation of the vertebral body it becomes pulled out and flat, and there is no counter pressure exerted against the transverse process. The latter, following the forward pull of the rib moves more forward into a frontal plane. As the convex side rib strains against the body and the transverse process on its side, the steadily increasing pressure causes it to become kinked or angulated at the weakest point of its body. This point is the costal angle, and it is here where the rib shows the greatest degree of deformation.

Another factor is added to the deformation of the rib by the pressure of the abdominal and thoracic musculature at the anterolateral portions of the body (Plate XX, 1). It would be erroneous to believe that it is the mechanical effect of the rib pressing against the transverse process and the vertebral body which rotates the body. It is the vertebral body with its torsion and rotation, rather, which is primarily leading in the deformity and not the rib; still, as the convex side rib is coiled against the vertebral body a great deal of strain is stored up which materially contributes to the rotation and torsion, so that in due course, rib and vertebral body exchange their deforming effects upon each other. Originally rotation is the result of the natural propensity of the spine to rotate while bending laterally, as provided by the particular arrangement of the dorsovertebral articulations. But sooner or later the counter effect of the twisted and coiled rib on the convex side makes itself felt so that the rib also, deforming and deformed, passive as well as active, becomes a factor in the whole scheme of deformity.

Nor is all pressure and pull between rib and vertebra confined to the side of the convexity. From here the rotating vertebrae transmit a pull through the length of the rib and through the sternum to the other side, and impart a mechanical effect to the concave side rib and back to its transverse process. Were the rib as rigid as the spinal column itself, a good deal of leverage could be effected upon the latter through the costal ring; but the rib itself is so elastic and pliable as compared with the spinal column that it acts more like a spring than a lever; so that, when tension or pressure is applied to the anterior portion of the rib a good deal of it becomes lost in the elasticity of this bone before it reaches the spinal column. An attempt to untwist the

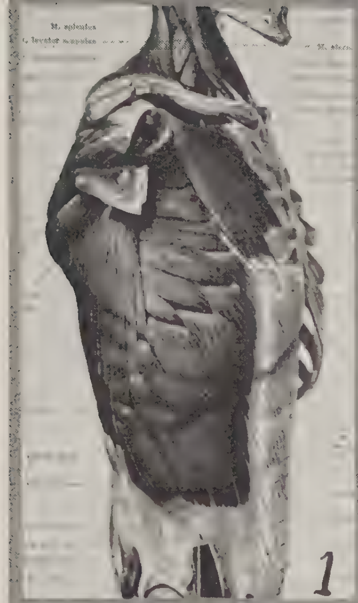
PLATE XX

Fig. 1.—Anterolateral musculature of thorax and abdomen. (After Braus.)

Fig. 2.—Scoliotic pelvis. Deformity of pelvic inlet. Asymmetry of sacrum.

Fig. 3.—Scoliotic pelvis. (After Braus.) Sacrum is included in the scoliosis. Note asymmetry.

Fig. 4.—Deformity of thorax as a whole. Note costal deformity.



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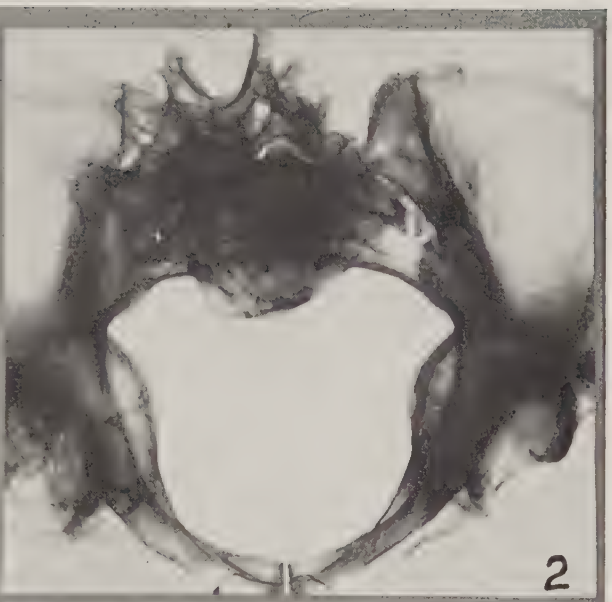

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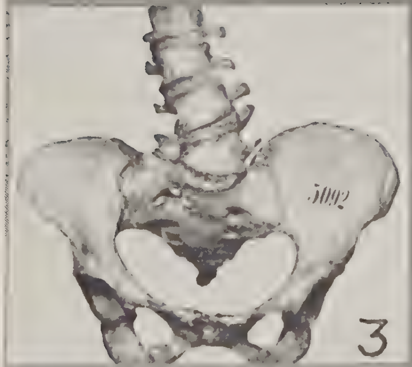

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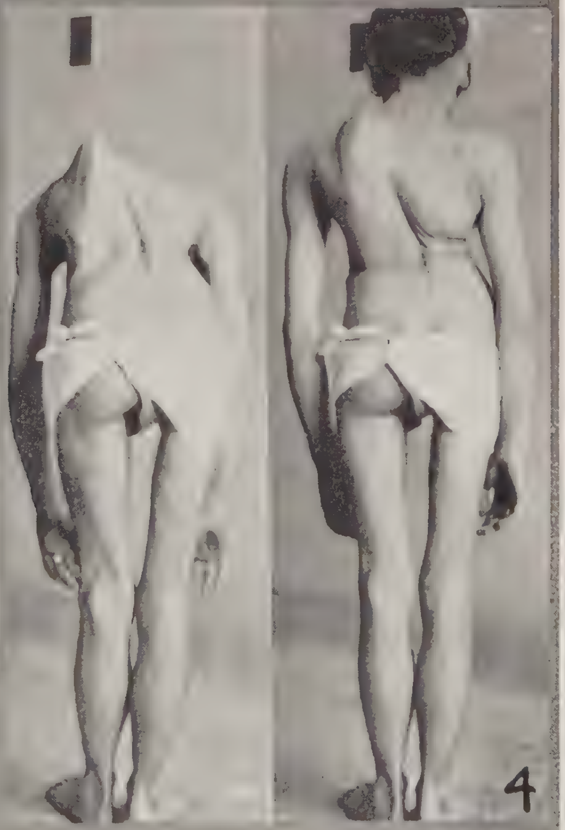

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PLATE XX

vertebral column by a force applied to the side or anterior portion of the rib would be like trying to lift a stone at the end of an elastic switch or rod.

So, we see that a good deal of independent deformation of the ribs is produced before any portion of the force can make a mechanical impression upon the more rigid spine. We may say, then, that the deformation of the spinal column leads and the ribs follow, that the ribs are not being deformed by the twist of the spinal column alone, but by other deforming factors as well, and that the deformity of the ribs also has its countereffect upon the spinal column. The thoracic cage, as a whole, is not composed of rigid levers from which the vertebral column can be regulated, but it consists of comparatively elastic structures which undergo their own individual deformity in addition to that imparted to them primarily by the rotating spine. Now we understand why it is so difficult if not impossible to control the rotation of the spine by applying force to the ribs (McKenzie-Forbes[43, 44]). The difficulty lies in the fact that, due to the elasticity and pliability of the ribs, one cannot obtain a purchase through them upon the vertebral bodies, and that the rib itself yields to deformation before a mechanical effect is transmitted to the spine.

7. The Sternum

In regard to the position maintained by the sternum in the scoliotic thorax the opinions differ. Fauconnet and Hoffa[61, 62] thought that it is more or less displaced to the concave side. Schulthess[141] noticed the tendency of the sternum to move concavely at its lower end in left convex scoliosis, while in the right convex curve he found a shifting of the sternum and the thorax to the convex side. The consensus of opinion seems to be that the lower the dorsal curve the more the tendency of the sternum to deviate convexly. Feiss[39] explains the deviation of the sternum by action of the abdominal muscles, maintaining that the lumbodorsal curves which deflect the whole thorax toward the side of convexity also deflect the sternum in the same direction, while in the higher curve, the deviation of the sternum varies, being either concave or convex.

8. The Thorax as a Whole

Let us recall that the ribs, besides the deformity which is imparted to them by rotation and torsion of the spine, also show independent deformation as a result of their greater plasticity. In this independent deformation of the rib the most important factor is the lateral tension stress produced by the muscles of the lateral abdominal wall (Feiss,[39] Plate XX, 1). These muscles become taut on the convex side and exert a diagonal pressure upon the lateral and anterior portions of the rib. With increasing deformity the tension of these muscles on the convex side also increases, and with it their mechanical effect upon the ribs. In this manner the rib deformation results quite independently of the rotation and lateral bend of the vertebral bodies. We also find that the direction of the ribs is changed. On the convex side they become divergent and elevated, on the concave side they are convergent and crowded downward (Plate XX, 4). The intercostal muscles act as a check against extreme displacement of the bodies and anterior ends of the ribs. In upright standing the lower costal margin usually clears the pelvis anteriorly, but in the slouched position an impingement often takes place which sometimes gives rise to subjective symptoms (Gaenslen[48]). The pain produced by this impingement is attributed to the irritation of the inguinal and iliogastric nerves (Rogers[118]).

9. The Scoliotic Pelvis

The first description of the scoliotic pelvis is that of Rokitansky[119, 120] (1836). He believed that an entirely normal pelvis does not occur in scoliosis, and that a scoliotic asymmetry of the pelvis is a constant factor in lateral curvature of the spine. This opinion, however, is not generally accepted. We are rather inclined to believe with Bouvier[19] that deformities which do not involve the last lumbar vertebra have no effect upon the pelvis. Lorenz,[87, 88] being of the same opinion, states that pelvic asymmetry exists only if the sacrum is involved in the curve. The older opinions that the sacrum is the primary cause of the scoliosis are being more and more refuted. Reijs,[114] who made accurate measurements of the scoliotic pelvis, found definitely, that pelvic asymmetry occurs when the sacrum is included in the scoliotic curve, but, if the latter ends above the 5th lumbar vertebra, then no asymmetry of the pelvis ensues. An asymmetrical pelvis can be observed without scoliosis, and vice versa, even severe scoliosis may be associated with a symmetrical pelvis. In cases in which the pelvis took part in the deformity, Reijs found that the contracted half of the pelvis was on the side of the convexity of the curve.

According to Breus and Kolisko[21] the principal characteristic of the scoliotic pelvis is an asymmetry of the iliac portion expressed by a greater inclination of the pelvic half which bears more body weight (Plate XX, 2, 3). On this side also the pelvic ring appears narrowed posteriorly by the stronger projection of the acetabulum into the pelvic ring. As a result the oblique diameter on this side of the pelvis is shortened. With exception of the rachitic cases the asymmetry of the scoliotic pelvis does not assume greater degrees. In the rachitic type of scoliosis, if the sacrum is included, it shows a curve opposite to one prevailing in the lumbar section, and with this sacral curve the whole deformation of the pelvis harmonizes. The sacrum appears not only curved but also tilted, so that the lateral masses on the concave side point lower than those on the convex side. The os ilei on the convex side is also carried farther backward than on the concave side, and the concave half of the sacrum appears shorter and thicker, the sacral foramina smaller. On the side of the convexity again the innominate line shows a sharper curve and the whole convex half of the pelvis occupies a more frontal plane, while the concave side observes a more sagittal direction. In accordance with the twist of the os ilei we also see in the scoliotic pelvis that the convex side acetabulum is rotated into a more frontal plane. Lorenz,[87, 88] who first described the scoliotic pelvis in connection with scoliosis, sees in the pelvic deformity an accentuation of the physiologic torsion (Fischer[42]), the right pelvic half showing a left spiral turn and vice versa.

In the rachitic pelvis we see the torsion phenomenon develop to a higher degree, due to the fact that here the deformity of the spine is often very pronounced, and that the primary curve is lower in the spine and, therefore, has greater influence upon the deformation of the pelvis; also, the pelvic bone is here more plastic and the deforming factor becomes more effective as it operates earlier in life. It has been pointed out that pelvic asymmetry and scoliosis may exist entirely independent of each other. Vertebral assimilation, wedge formation, oblique pelvis, contracted or flattened pelvis, they all may occur without scoliosis. In many instances, pelvic asymmetry and scoliosis must be regarded as coordinated phenomena originating possibly from a common cause. Static conditions, such as dislocation of the hip, hip disease, may be the background of a static scoliosis, and also be factors in the pathogenesis of pelvic asymmetry. Combinations of scoliosis with pelvic asymmetry have been described frequently. Kirmisson[75] (1907) describes a case of pelvic malformation, rather complex, associated with malformation of the vertebral bodies. Moutier[100] records a pelvic deformity where the smallness of os ilei resulted both in obliquity in the pelvis and in scoliosis of the superincumbent spine.

10. Muscle Pathology in Scoliosis

H. Virchow,[151] a careful investigator of the muscle conditions in scoliotic spines, finds that the changes in the muscles are of secondary character. Shortening of the muscle is not due to primary contracture or functional atrophy, but, as he explains, to the restriction of motion. Degeneration of muscle has been found but only as a secondary event, and there are cases of advanced scoliosis with strong secondary contracture of the muscles without degeneration. This does not exclude, however, that the secondary contracture of the muscles on its part again, influences the scoliotic deformity so that a vicious circle is established in which the skeletal deformity is first followed by muscle shortening, and this again contributes to the progress of the deformity. In the histologic examination of the muscles there is nothing to indicate a functional adaptation of the muscles to pathologic conditions.

VII. THE CLASSIFICATION OF SCOLIOSIS

1. Clinical Classification

As a practical, clinical classification the one devised by Schulthess[137] deserves most consideration.

(I). Primary Form Deviation or Malformation. Congenital Scoliosis.

(II). Scoliosis from Diseases and Acquired Anomalies.
  1. Constitutional Debility or Insufficiency. Habitual Scoliosis.
  2. Rachitic Scoliosis.
  3. Scoliosis in Disease, Such as Osteomalacia, Neoplasm, Tuberculosis, Arthritis, or in Injuries.

(III). Secondary Form Deviation. Pathologic Changes Outside the Spine, such as Thorax or Extremities.
  1. Secondary to Afflictions of the Nervous System. Paralytic Scoliosis, Neuritic, Spastic, Meningitic, Sciatic, Hysterical Scoliosis. Scoliosis from Tumors or from Traumatic Paralysis.
  2. Secondary to Afflictions of the Internal Organs. Respiratory Disturbances, Emphysema, Phthisis, Pleurisy.
  3. Scoliotic Attitudes from Circulatory and Cardiac Lesions.

2. Topographic Classifications

For practical purposes it is convenient to classify the curves according to their locations and distribution. The most authentic figures as to distribution of curves in the different sections of the spine and their relation to ages are those compiled by Schulthess.[140]

In general we find more left than right convex curves. The greatest number of left curves have their apex at the dorsolumbar junction; and the next greatest number have their apex at the 4th dorsal. Of the right side curves, the greatest number have their apex at the 7th dorsal, and the next greatest at the 1st and 2nd lumbar.

All in all, scoliotic deviations are more frequent at the lumbodorsal level at the left side, and at the middorsal level at the right side. The ratio of all right to all left primary curves is given by Schulthess as 46 to 54 per cent, showing a slight preponderance of the left side curve.

Where a single curve exists we see that the left is more frequent than the right; the greatest number of left single curves, including total scoliosis, have their apices between the 9th and 11th dorsal.

a. The Left Total.—The apex is at the 9th or 10th dorsal, and the extent of the curve from about the 6th dorsal to the 2nd lumbar.

Much less frequent is the right total curve, the frequency ratio between right and left being as 10 to 90. A number of these left total curves show concave torsion and for this reason may not be considered as structural scoliosis. The majority of these cases, however, show the rotation and torsion on the convex side. The total incidence of this type of curve is 15 per cent (Plate XXI, 1).

b. The Cervicodorsal Scoliosis.—This is most frequently on the left side with the apex at the 3rd or 4th dorsal, more often combined with secondary curves lower down. This curve is usually of a rachitic nature and is characterized by sharp deviation and strong tilt. The incidence of this type of scoliosis is 3.6 per cent (Plate XXI, 2).

PLATE XXI

Topography of Curves

Fig. 1.—Left total curve.

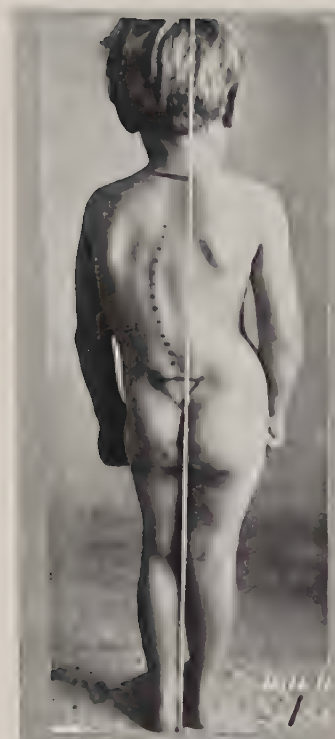
Fig. 2.—Cervicodorsal curve.

Fig. 3.—Dorsal curve.

Fig. 4.—Lumbar curve.

Fig. 5.—Combined dorsolumbar curve.

Fig. 6.—X-ray of Fig. 5.



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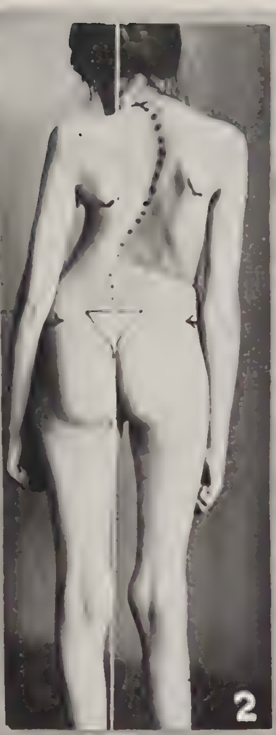

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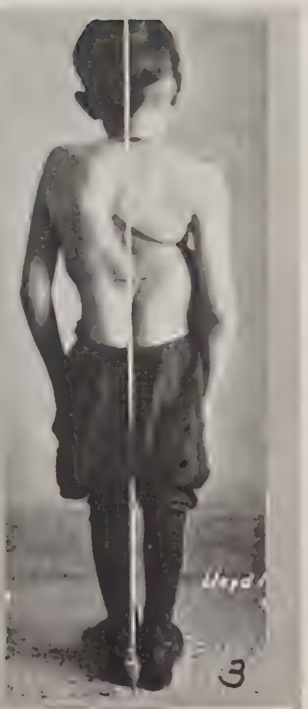

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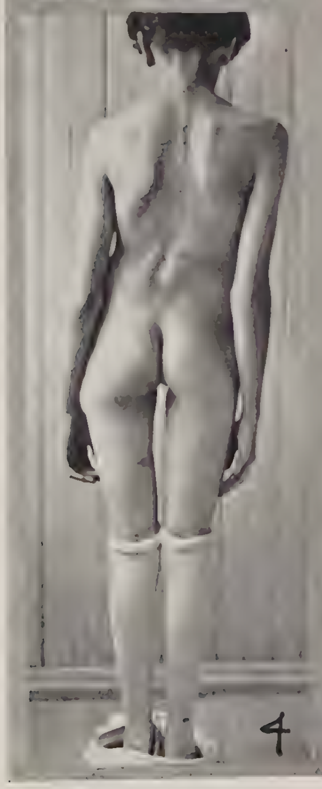

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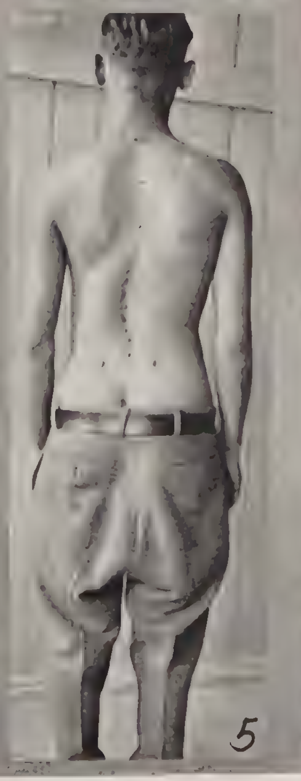

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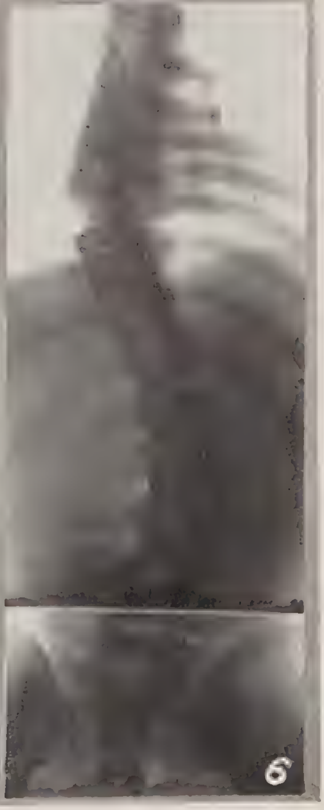

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PLATE XXI

c. The Dorsal Curve.—This curve has a considerable tendency to develop secondary curves, especially the one on the right side. The right single dorsal curve also shows a great tendency to overhanging or decompensation. Incidence about 20 per cent (Plate XXI, 3).

d. The Lumbodorsal Curve.—This curve is found preponderatingly on the left side. Ratio of left to right is 80 to 20. The greatest number has its apex at the 12th dorsal. It is a well-defined clinical entity in rachitic scoliosis. Incidence about 18 per cent.

e. The Lumbar Scoliosis.—This also is prevailingly on the left side, though not so much as the former type. The greatest number shows the apex at the 1st and 2nd lumbar. The predisposing condition of this type is habitual scoliosis following flat back. The total incidence of this scoliosis is, according to Schulthess, 11.7 per cent (Plate XXI, 4).

f. The Combined Dorsal Scoliosis.—There is a primary dorsal and secondary dorsocervical and dorsolumbar curve. The primary dorsal curve is preponderatingly on the right side, the secondary curves are on the left. Ratio of right to left primary curve is as 80 to 20. The greatest number of these cases have the apex at the 7th dorsal. This is the most frequent form of all. The underlying causes are habitual or constitutional conditions and rickets. This type furnishes the largest percentage of the so-called habitual or idiopathic scoliosis. Its total incidence is 30 per cent of all curves (Plate XXI, 5, 6).

3. Age and Distribution

The maximum occurrence of scoliosis covers the period from the eighth to the fourteenth year. The right convex from the eighth to the seventeenth, the left convex from the eighth to the fifteenth year.

4. Sex and Frequency

Male patients show more left convex curves than right, the ratio being 65 to 35 per cent. Total scoliosis is more frequent in the male, the ratio being 3 to 1. Lumbar scoliosis is more frequent in the female, at a ratio of 2 to 1 (Scholder[136]).

VIII. THE CLINICAL PATHOLOGY OF SCOLIOSIS

1. Congenital Scoliosis

Although this condition was apparently first described by Mery[96] in 1706, its existence was denied for over one hundred years. At the beginning of the twentieth century a number of important contributions appeared (Hirschberger[58] and Athanassow[9a]). Hirschberger in an extensive treatise collected forty-two cases in the literature up to 1900. He defines congenital scoliosis as one caused by intrauterine abnormal pressure, or defects in the normal development of the vertebra.

In congenital scoliosis the curve is sharper than usual, the rotation is less, curves develop above and below the original seat similarly to the compensatory curve in an acquired scoliosis. The absence of rachitic changes and the signs of arrested development of the vertebral bodies are important points (Athanassow[9a]). The incidence among newborn children is extremely small (Coville) in comparison with the more frequent manifestations of congenital scoliosis later in life (Plate XXII, 1, 2, 4).

a. Numerical and Morphologic Variations and Congenital Scoliosis.—Thanks to the newer investigations of Boehm[14] and others, we are now in better position to classify and subdivide the group of congenital scoliosis upon an anatomic basis. Grossly the material may be divided into scoliosis due to numerical variations, and that due to morphologic anomalies. The numerical variations are caused by assimilations to cranially or caudally adjacent portions of the spine. Of the greatest interest for the pathogenesis of congenital scoliosis are the assimilations which occur in the lumbodorsal region. Here we find in caudal direction the sacralization of the 5th lumbar in various degrees, from the enlargement of the transverse process to complete double sacralization of the 5th lumbar vertebra; in cranial direction there are the much rarer cases of lumbarization of the 1st sacral into a 6th lumbar segment. Both types may become influential in the formation of congenital scoliosis.

Numerical variations play a much less important rôle, however, than the second group representing the morphologic anomalies. To these belong the rudimentary development of vertebra, such as wedge formations, anterior or posterior clefts of the spine, all degrees of spina bifida occulta or manifesta, and other disalignments between the 5th lumbar and the sacrum. All these may constitute an anatomic basis for congenital scoliosis. We find the morphologic and numerical variations so scattered over the whole length of the spine than an arrangement of the curves according to their levels would appear difficult. The lumbodorsal junction is the most frequent location of the curves. In our own experience congenital deformities of the spine are apt to develop more rapidly and go to greater extremes the lower the anomaly is situated, and the greater, accordingly, the superincumbent weight.

So far as the relation of numerical variations to subsequent scoliotic deformity is concerned, we find that it is above all the asymmetrical development of the sacral end of the spine which leads to scoliosis. In the cranial portion of the spine numerical asymmetries lead to scoliosis by disturbing the normal relations between shoulder girdle and thorax. So we have unilateral elevation of the shoulder girdle (congenital elevation of the scapula) and asymmetry of the sacral wing (hemisacralization) as allied phenomena. Both may, but not necessarily do, lead to congenital scoliosis.

In the lumbodorsal section of the spine, there are anomalies and asymmetries of the intervertebral articulations; in the cervicodorsal section the asymmetrical development of the ribs which often cause congenital scoliosis.

In his evaluation of the congenital element, Boehm goes so far as to asso-

PLATE XXII

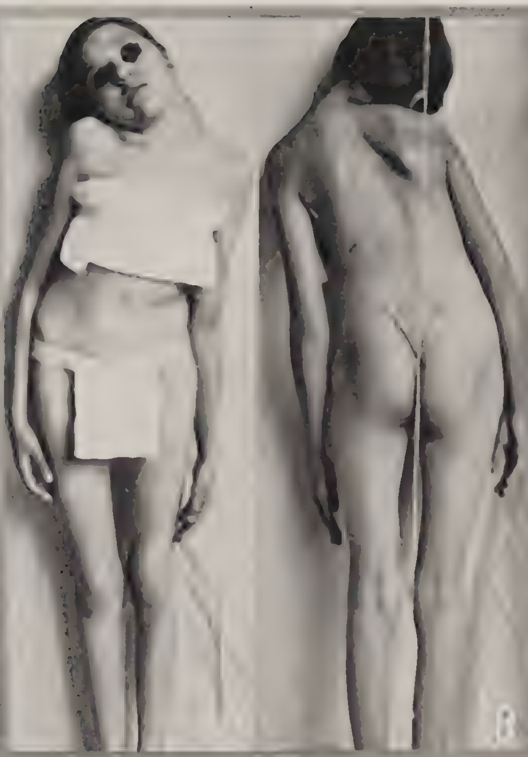
Congenital Scoliosis

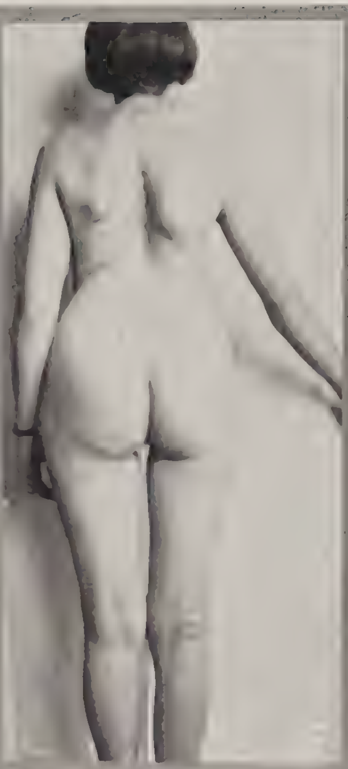
Fig. 1.—Cervicodorsal congenital scoliosis.

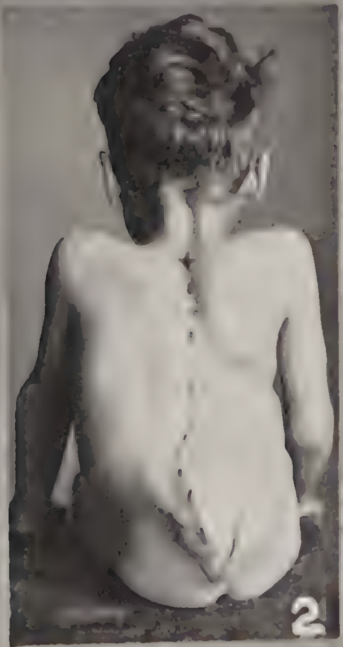
Fig. 2.—Lumbar congenital scoliosis.

Fig. 3.—Cervicodorsal congenital scoliosis. (See X-ray XXVI, Fig. 1, and operative findings XXVI, Fig. 4.) Note this patient stands erect only with some support.

Fig. 4.—Dorsal congenital scoliosis.







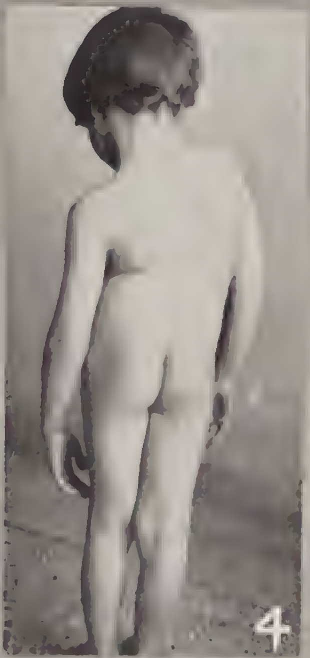


PLATE XXII

ciate even the so-called idiopathic scoliosis of the adolescent with congenital variations of the spine, believing that the effect of congenital anomalies or variations reaches into the 2nd decade of life where it produces a so-called idiopathic habitual scoliosis after a long period of latency.

b. Putti's Classification.—Putti[111] makes a more definite distinction between the numerical and morphologic causes of congenital scoliosis, and recognizes four types. In the first, the congenital scoliosis is due to abnormal pressure in utero, from lack of space, a positional deformity developing within the last month of uterine life after the skeleton has already assumed complete differentiation.

In the second type of congenital scoliosis the deformity does not develop until the age of four or five, becoming more and more pronounced. The child's back is straight at birth, but a point of increased lanugo, or tuft of hair, redness of the lower portion of the spine, denotes the congenital anomaly which is usually a cleft of the posterior element of the vertebra, i.e., a spina bifida occulta. In this type the principal deformity is a low sacrolumbar or lumbodorsal curve, very sharp and rigid, and only incompletely compensated by the supericumbent portion of the spine. Often the underlying causes are anomalies of the ventral element of the vertebra, for instance, the formation of a half body. In this type the deformity very often goes on to an extreme degree if the anomaly is situated low in the spine.

In the third type congenital curvature is found as a combination of metameric with morphologic anomalies of the vertebrae. Such a type develops slowly, late after birth and never attains the severity of the other type. This type is characterized by a high degree of scoliosis and kyphotic curves, severe torsion, a costal gibbus and sometimes muscular anomalies.

The fourth type is the shoulder type. There is an abnormal relation between spine and shoulder girdle and the position of the latter is pathognomonic and is the dominant element in the clinical picture. To this belongs the scoliosis that is found in congenital elevation of the scapula.

Of especial clinical importance are also the anomalies at the lumbodorsal level. Wedge formation of the vertebrae plays an important part in congenital scoliosis, the benign forms occurring in the upper dorsal curve (Drehmann[31, 32]), while those occurring in the lower dorsal and lumbar spine are more malignant and very difficult to compensate. The latter deformities usually make rapid progress after their first appearance. These are cases often associated with spastic conditions such as spasms of the legs, hyperactive patellar reflexes, Babinsky's sign, bladder paralysis, and clubfoot deformities.

There is much discussion over the question whether the scoliosis is the primary element leading secondarily to the abnormal development of the vertebral bodies (Hackenbroch[54]), or whether the scoliosis is the secondary element. It is possible that in cases of positional intrauterine deformity scoliosis develops first, and that it secondarily causes defective development of the vertebrae (Mueller[101]). Putti, however, considers the malformations of the vertebrae as the primary factor excepting the very rare type of positional curves which is due to the intrinsic pressure of the uterine wall.

However, other cases of congenital scoliosis with malformation of the vertebral bodies are reported in which there are good indications that the deformity was of exogenous origin, that is, caused by intrauterine pressure and not by primary developmental aberrations (Hackenbroch[54]), and it is believed that congenital scoliosis of exogenous or extrinsic origin is more frequent than is generally assumed.

c. Associated Deformities in Congenital Scoliosis.—

(1) *Congenital Scoliosis and Congenital Elevation of the Scapula (Plate XXIII, 1).*—This combination has already been described as Putti's fourth type of congenital scoliosis, indicating the effect of a spinal anomaly upon the shoulder girdle. According to Horwitz[65] scoliosis accompanies congenital elevation of the scapula in 47.8 of all cases; in some of these the congenital elevation is the secondary symptom. The metameric anomalies of the thoracic skeleton resulting in deviation of the spine, often also associate with morphologic and numerical anomalies of the costal element (cervical rib), and these again produce the elevation of the scapula. Sometimes we find that the curve points its convexity in the direction opposite to the elevation of the scapula. Where, on the other hand, the scapula is elevated at the side of the curve, it would seem that the congenital elevation is the effect rather than the cause of the spinal deformity.

Among eight cases of spinal anomalies observed by Staub[144] there were three in which costovertebral anomalies with unilateral elevation of the shoulder blade existed together. The spinal anomalies consisted in wedge formation, fusion of the ribs, and suppression of vertebral bodies, hemivertebrae, bifurcation of the ribs, etc.

(2) *Congenital Scoliosis and Sacralization (Plate XXIII, 4, 5).*—Among all the anomalies of the vertebral bodies encountered in congenital scoliosis the most frequent is the malformation of the 5th lumbar (Adams[2,3]). According to Adams scoliosis due to this anomaly manifests itself in various types; in some cases the scoliosis develops late; there is hardly a costal gibbus, and lumbar rotations as well as dorsal rotations are very little pronounced. In other types the deformity appears comparatively early and produces marked rotation symptoms. The question is to what degree is the sacralization of the 5th lumbar responsible for the scoliosis? That it produces an asymmetry of the pelvis, causing the latter to become inclined to one side, is obvious, but whether this is enough to produce scoliosis (Boehm) or not is another question. In Dwight's collection described by Boehm there was found among nineteen spines presenting an asymmetrical sacralization only one case of scoliosis. In the explanation of the mechanism by which scoliosis is produced in cases of anomalies of the articular processes of the 5th lumbar vertebra, attention is called by Adams to the fact that this vertebra is kept from gliding forward against the sacrum by the articular processes; if these are missing on

PLATE XXIII

Fig. 1.—Congenital elevation of the scapula associated with congenital scoliosis.

Fig. 2.—Cervical rib associated with congenital scoliosis. (See also Plate VII, Fig. 3.)

Fig. 3.—Habitual scoliosis, combined type: right dorsal, left lumbar.

Fig. 4.—Sacralization of lumbar spine as cause of congenital scoliosis. (See also VII, Fig. 4.)

Fig. 5.—X-ray of Fig. 4.

Fig. 6.—Habitual scoliosis—left total.

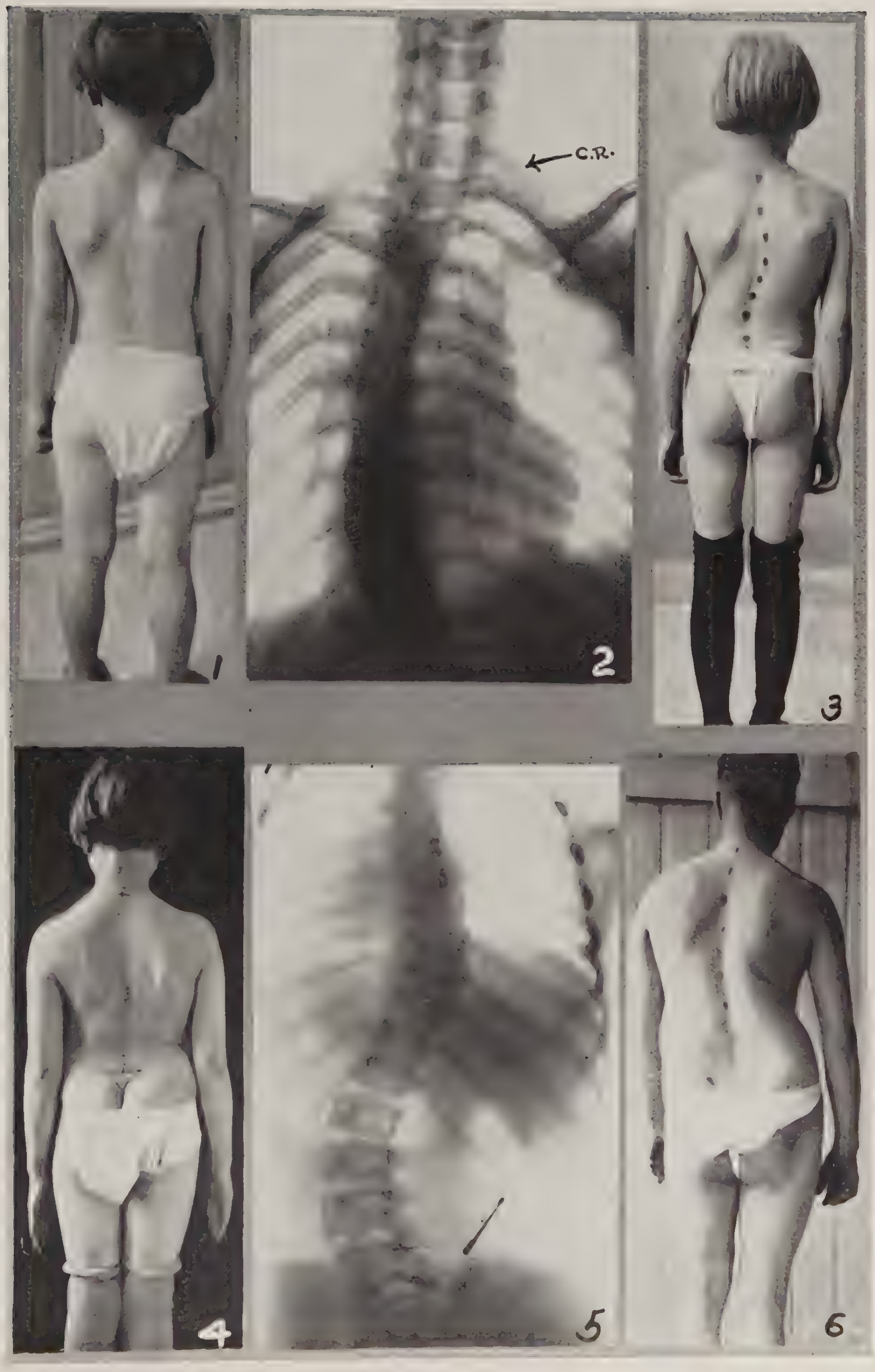


PLATE XXIII

one side, or malformed, the vertebral body may undergo an adjustment of its position. We find during the rapid growth in puberty, when the lumbosacral angle becomes increased, and the ligaments become relaxed, while the apophyses of the 5th lumbar vertebra are not yet formed, that the most favorable condition for a shift of position of the 5th lumbar is created, causing a rotatory movement of this vertebra with lateral deviation. Scoliosis based upon slight malformation of the 5th lumbar is usually tardy and late in appearance. The deformation of the 5th lumbar may pass entirely unobserved through life as shown by the incidental discovery of asymmetries in the x-ray picture. In cases of this kind, acquired factors, such as rickets, attitudes, etc., must be regarded in the light of contributory elements which ultimately determine the appearance of the congenital scoliosis.

(3) *Congenital Scoliosis and Cervical Rib. (Plate XXIII, 2).*—That cervical rib is frequently associated with scoliosis has been mentioned (Plate VII, 3). There are usually other anomalies of the vertebral bodies present, such as wedge formation, and often a spina bifida occulta, anterior or posterior clefts. Scoliosis is by no means a constant or frequent symptom of the cervical rib but rather the exception. According to Kramer, who reports a series of seven cases of the so-called cervical rib scoliosis, other associated spinal anomalies determine the scoliosis.

d. The Latency in Congenital Scoliosis.—Some of the types of congenital scoliosis make their appearance so late that its congenital character has long been doubted (Mouchet and Roederer[99]). This is especially true of some of the so-called idiopathic scolioses which have their origin in some congenital deformity, but which, owing to their particularly slow development, do not make their appearance clinically until the second half of the second decade. We can understand this period of latency in congenital scoliosis when we consider that, in some instances, the deflection caused by the spinal anomaly is not very great and that, therefore, during a certain period of life, the reserve power of the musculature is capable of maintaining equilibrium and of preventing the further breaking down of the spine. It is the strain and stress upon the musculature which occurs during the 3rd period of rapid growth, together with constitutional factors, such as rickets and habitual malposture or faulty attitudes which finally succeed in bringing about the manifestation of the deformity.

2. Physiologic Scoliosis

As indicated, this form is considered to have its source in the normal lateral deviation of the spine, whether this be caused by the position of the aorta, by righthandedness, or, according to the latest theory, by asymmetry of the diaphragm (Jansen). It seems that this type of scoliosis develops first by translatory horizontal shifting of the vertebrae, but it is soon complicated by an inclination deformity of the superimposed section of the spine. So far as its clinical entity is concerned, it belongs to the great group of so-called idiopathic or habitual scoliosis, and it would be better to designate it as a phase of the idiopathic scoliosis, being distinct from the latter only by the absence of wedge formation of the vertebrae and the persistence of the physiologic anteroposterior curve (Farkas). We see in this type that as soon as the inclinatory deviation is added to the picture the oblique-shaped vertebra, which denotes the translatory shift, the latter no longer represents the only change, but that there appears at the apex a wedge-shaped vertebra such as we find in the idiopathic or habitual scoliosis. In this sense, the physiologic scoliosis is the forerunner of the habitual.

3. The Habitual Scoliosis

Neither the distribution of the curves nor the definite pathologic changes characterize this type of scoliosis. It occurs both as a right dorsal or a left total form, and is distinguished among the other groups of scoliosis by the fact that no concrete or definite pathologic cause can be assigned to it. Nevertheless, the term of idiopathic scoliosis indicating the absence of a definite underlying cause is not adequate and the term habitual scoliosis is more appropriate.

a. **Types.**—There are two principal types: (1) the right dorsal combined type. It is believed that this form develops in accentuation of physiologic lateral curves of the spine (Plate XXIII, 3); (2) the left total scoliosis (Plate XXIII, 6).

b. **Predisposition.**—The prescoliotic stage for both types are postural defects and attitudes as described in the section on Prescoliosis. In both forms the original type of displacement is the translatory or side shift of the vertebrae; inclination deformity is superimposed later. The flat back predisposes especially to this type of scoliosis with its poorly developed muscles and its low resistance against deforming influences. The curved back is practically safe against scoliotic deformity.

c. **Sex.**—There is a great preponderance of the females over the males. For this, various explanations have been ventured. It is understood that the generally better developed muscles in boys, due to their greater physical activity and their better constitutional development, the fact that the male constitution is less severely influenced by physiologic processes of puberty, together with the sexual differences in the formation of the pelvis and in the mechanism of gait, all exert their influence to make this deformity strongly predominant in girls.

In the writer's series of seven hundred cases the habitual or idiopathic type constitutes 48 per cent of all scolioses.

4. The Rachitic Scoliosis

Here we may distinguish the following types: (a) the lumbodorsal, or lumbar kyphoscoliotic form; (b) the combined lower dorsal scoliosis; (c) the high cervicodorsal form.

PLATE XXIV

Fig. 1.—Rachitic scoliosis—lumbodorsal type.

Fig. 2.—Rachitic scoliosis, combined type: left cervicodorsal, right dorsolumbar.

Fig. 3.—Rachitic scoliosis. High cervicodorsal.

Fig. 4.—Paralytic scoliosis. Total.

Fig. 5.—Paralytic scoliosis. Upper extremity also involved.

Fig. 6.—Paralytic scoliosis. Lower extremity also involved. (B) After treatment.

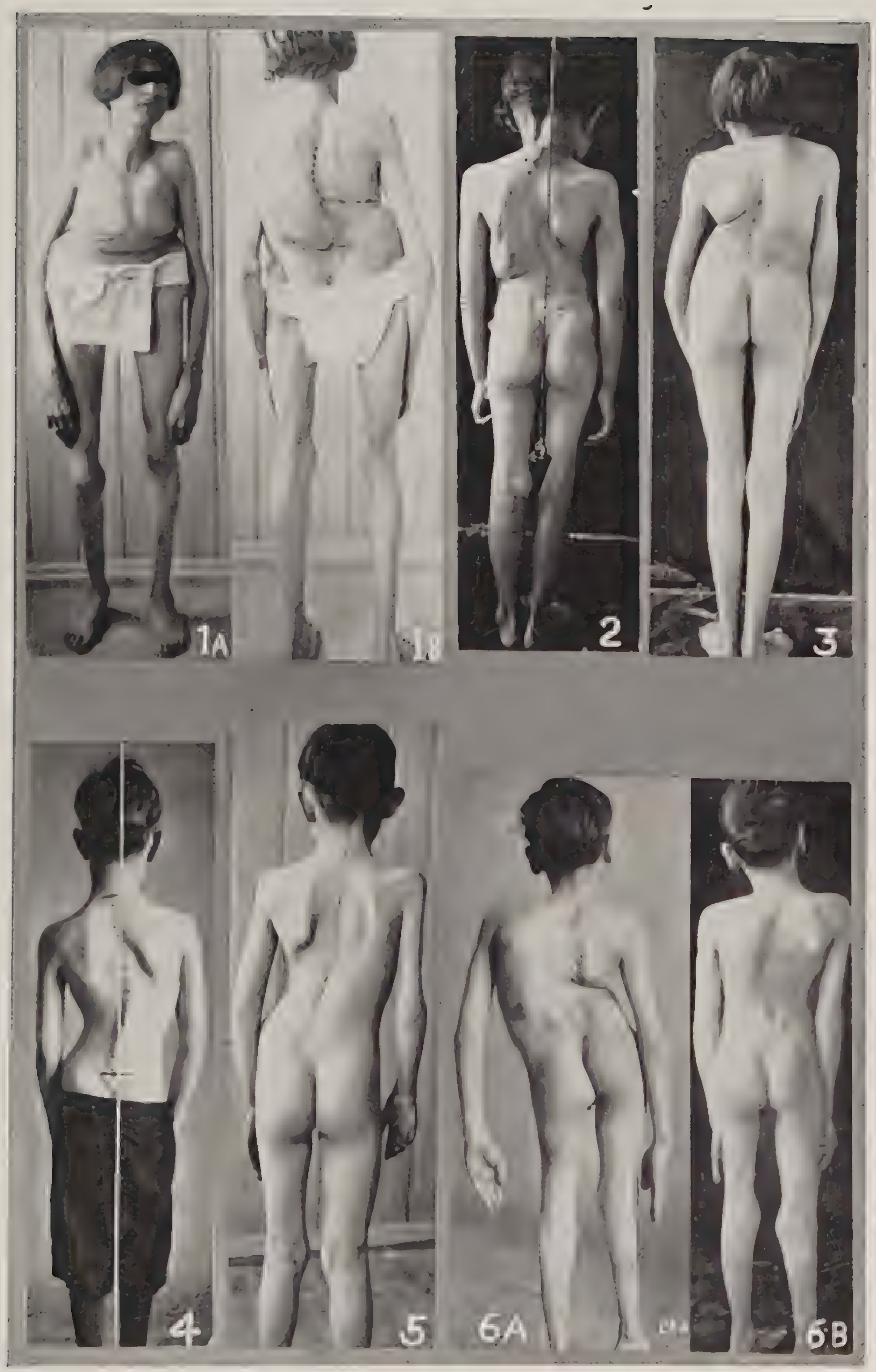


PLATE XXIV

a. The lumbodorsal or lumbar type, the direct sequence of the usually low dorsal or lumbodorsal anteroposterior rachitic curve. According to Hoffa[60, 61] and Farkas[38] it is simply the anteroposterior curve twisted from the sagittal into the frontal plane. This single, low lumbodorsal curve, however, is by no means the typical form of rachitic scoliosis of early age (Plate XXIV, 1).

b. The Combined Type.—This curve is more frequently seen in rickets even as early as the first or second year of life. Its usual location is the right lumbar region and it is associated with a high dorsal curve in the opposite direction. We find it combined with flattening of the skull and other rachitic stigmata; deformation here also occurs by translation or side shifting (Plate XXIV, 2).

c. High Cervicodorsal Type.—The most characteristic, though the least frequent of all rachitic curves, is the high cervicodorsal type.

This high dorsal or dorsocervical curve develops into severe degrees of deformity, producing scoliotic wry neck and extreme deformities of the ribs (Plate XXIV, 3).

The rachitic curves of the lumbar or dorsolumbar sections are characterized by early occurrence, in the first years of life, by rapid development and great tendency to produce tilts or overhangings of the body in early stages and by the inability to develop sufficient counter curves to restore body balance. The thorax appears short and stubby. Other typical rachitic changes of pelvis, thorax or the lower extremities, usually establish the diagnosis.

The total frequency of rachitic curves in the writer's series was 9 per cent.

5. The Paralytic Scoliosis

This is a true inclination type. The deficiency of the musculature is the determining factor in deformation. Pathologic inclination with subsequent muscle contracture develops before an intervertebral or interarticular relaxation could occur in contrast to the congenital or rachitic types, which show, primarily, a translatory or horizontal shift of the vertebral bodies.

The incidence of paralytic scoliosis in the writer's series of seven hundred scolioses is 31 per cent.

a. Types.—In this group also there are no prominent types. A great many cases show total scoliosis either right or left. The tilt develops early and is very marked, the body as a whole showing very poor ability to retain its balance by compensation. A peculiar feature of paralytic curvature of the spine is not only the irregularity of its form but frequently also the comparatively long period of latency. This insidiousness in development is an important factor; it has much to do with the degree and distribution of the paralysis of the back muscles. The distribution of paralysis also determines the type and degree of scoliosis (Plate XXIV, 4).

b. Distribution of Paralysis.—

(1) *Bilateral paralysis* of the musculature of the back usually leads to simple lordosis. The body is thrown backward in order to save its equilib-

rium and to prevent the forward dropping of the nonsupported back. Paralysis of the abdominal muscles also causes anteroposterior curves of the round hollow back or round back type, the upper portion of the thorax being sharply inclined forward.

(2) *Lower Extremities; Static Scoliosis.*—Paralysis of one of the lower extremities with its frequent shortening creates a static condition of inequality or pelvic obliquity which is not without effect upon the spine. If the long muscles of the back are not involved, then the oblique position of the pelvis simply results in a static scoliosis and the spine may retain its mobility for a considerable length of time, being under control of the muscles of the back and no permanent scoliotic deformity need develop.

(3) *Unilateral Paralysis of Back Muscles.*—In unilateral paralysis of the long muscles of the back, however, conditions are different, especially if such paralysis is combined with shortening of one of the extremities. Then a lumbodorsal curve develops with a convexity toward the sound side. In all paralytic curvatures of the spine caused by unilateral paralysis of the long muscles of the back, the rule is that the convexity points toward the sound side and not toward the paralytic side. One might possibly expect off-hand that the sound side would become contracted and force the spine to cave in on this side, but a short reflection will show such a situation dynamically improbable. The body trying to save its equilibrium must go into convexity toward the sound side, the trunk retaining just enough overweight on the affected side to hold the well muscles in a state of passive tension. This is the only way which, under the conditions, the equilibrium of the body can be maintained. The excess of body weight is on the paralyzed side, held there against the passive tension developed by the muscles on the sound side, which hold the body back from collapsing toward the affected side. Anchored under tension to the sound side muscles, the body is able to maintain its balance.

This is in keeping with the experiments of Arnd,[9] who found that upon removal of the muscle masses on one side, the spine would incline toward the side of the removed muscles, bringing again its convexity to the nonoperated or sound side.

Similarly, children with partial paralysis of the muscles of the trunk are observed sitting with the trunk usually shifted toward the sound side, that is, with the convexity pointing to it. If there is a shortening of one limb in addition to the paralysis of the back muscles, then the resulting obliquity of the pelvis, according to its direction, may either accentuate or neutralize the deforming tendency of the paralytic muscles of the back. For instance, in the event of a left paralysis of the muscles of the trunk and of the lower extremity, one would expect a right total scoliosis to develop by reason of the paralysis of the trunk. If there is, in addition, a shortening of the left leg with a lowering of the left side of the pelvis, a left lumbar curve would result, which, in this case, would neutralize to a degree the right dorsal scoliosis. The same effect may be brought about by a contracture of the lower extremity (Plate XXIV, 6).

PLATE XXV

Fig. 1.—Scoliosis in spastic paralysis.

Fig. 2.—Hysterical scoliosis—x-ray. All signs of scoliosis disappeared under anesthesia temporarily, and permanently after psychotherapy.

Fig. 3.—Sciatic scoliosis.

Fig. 4.—Arthritic scoliosis.

Fig. 5.—Case of Fig. 2 after psychotherapy.

Fig. 6.—Tabetic scoliosis. Charcot hip.

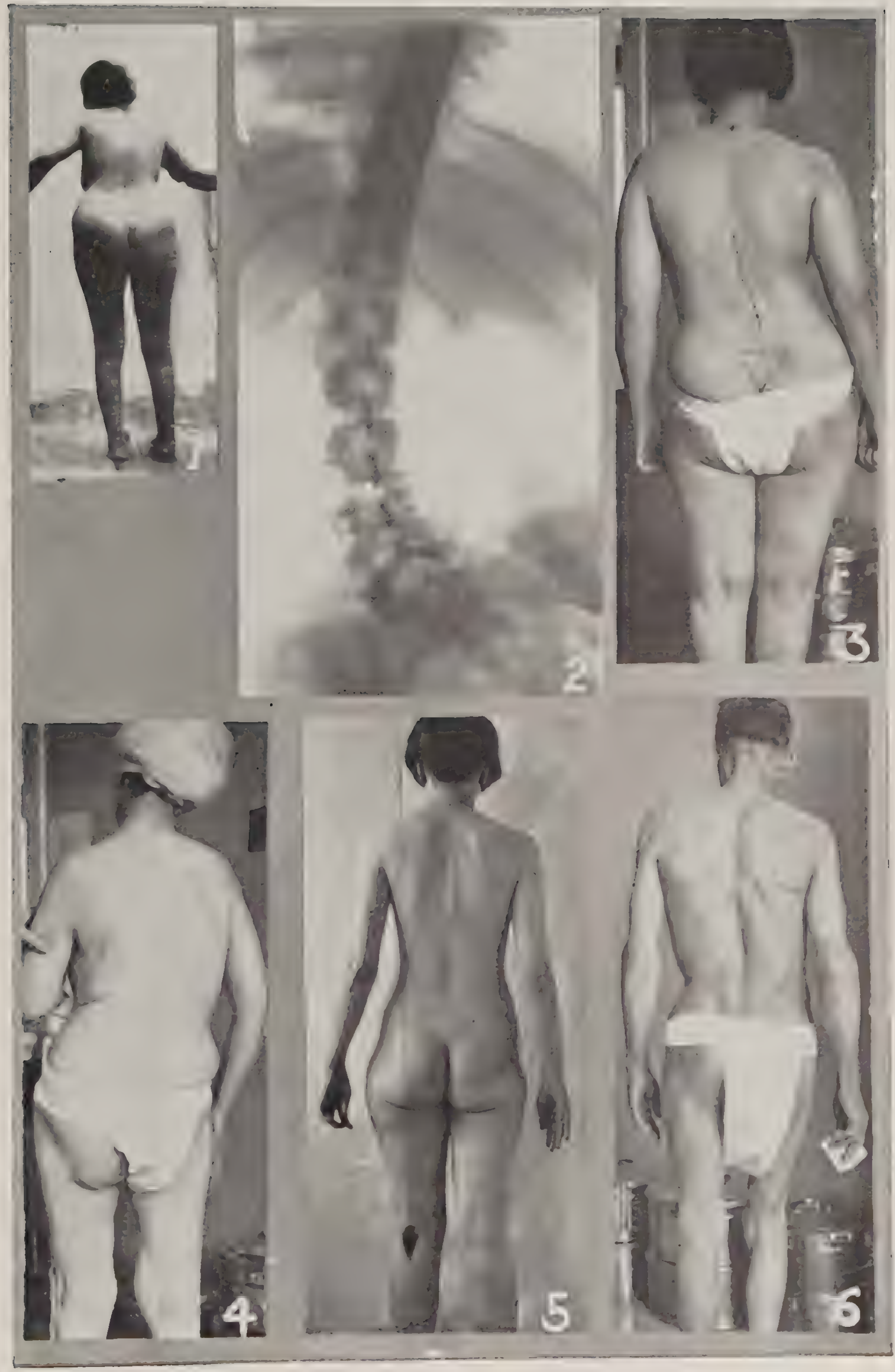


PLATE XXV

Because the lumbar spine retains, even in paralytic scoliosis, its mobility to a much greater degree and for a longer time than the dorsal section, the deviation does not become as marked in sitting as it does in standing.

(4) *Paralysis of the Upper Extremity.*—In paralysis of the upper extremity an effect can also be noticed upon the deviations of the spine (Plate XXIV, 5).

Paralysis of the deltoid and biceps on one side with inability of the arm to abduct, produces lateral curvature owing to the attempt of the patient to elevate the arm by inclination of the trunk to the nonparalyzed side. Such a scoliosis is further facilitated when the serratus anterior is involved, since then the unopposed pull of the trapezius muscle elevating the scapula becomes more effective. The convexity points to the side of paralysis. We also see high dorsal scolioses develop with convexity to the affected side in cases of arthrodesis of the shoulder performed for deltoid paralysis, and in other cases an already existing paralytic scoliosis may be accentuated after arthrodesis due to the efforts of the patient to abduct the arm and shoulder by means of the trapezius muscles and by inclination of the trunk.

c. Scoliosis in Spastic Paralysis.—We occasionally notice a secondary scoliosis in cases of spastic paralysis, though it is not an ordinary occurrence, since spasticity expresses itself rather in forward flexion in order to compensate for the flexed position of hip and knee. However, in spastic hemiplegia such a lateral deviation of the spine is not uncommon. It is produced by the equinus position of the lower extremity, by the contracture of knee and hip on the affected side together with the spastic contractures of the upper extremity. These curves, however, retain their mobility for a long time and only occasionally become fixed (Plate XXV, 1).

6. Neurogenetic Scoliosis

To this group belong two types of scoliosis: the hysterical and the sciatic scoliosis.

a. The Hysterical.—This type of scoliosis is a true contracture. Mechanically expressed, it is a pure inclination deformity. It is characterized by a total curve especially marked at the lumbodorsal junction. It is more an attitude of obliquity of the trunk than a true scoliosis. The anatomic basis of this type of scoliosis is the muscle contracture. The condition can be momentarily relieved by suspension or traction. Other hysterical stigmata are usually present (Plate XXV, 2, 5).

b. The Sciatic Scoliosis.—Scoliosis is a frequent complication of sacrolumbar or sacroiliac strains, with or without involvement of the sciatic nerve. It often follows sacroiliac or sacrolumbar disease, and it is present in idiopathic sciatic neuritis. This is a purely postural type of scoliosis, being voluntarily or unconsciously assumed by the patient in order to avoid painful stresses upon the sacroiliac or sacrolumbar junctions, or strains upon the lumbosacral plexus (Plate XXV, 3).

In the beginning when the sacroiliac symptoms are acute, the tilt of the body is to the sound side (contralateral), so that the convexity of a lumbar curve appears on the side of affection. This is done in order to deflect the body weight away from the very sensitive sacroiliac articulations. Later, however, this tilt is changed to the affected side, producing the convexity of the curve opposite the side affected. The object of this change of direction is obviously to relax the cords of the lumbosacral plexus. Sciatic scoliosis does not become rigid except in very extreme cases and is really a remediable deformity which disappears with the relief of the joint symptoms, or the subsidence of the secondary neuralgias of the lumbosacral plexus. Inasmuch as this form of scoliosis is symptomatic of traumatic conditions of the spine, especially of affections of the sacrolumbar and sacroiliac junctions, a more detailed description of the condition will be given in the respective chapter (see Chapter V).

7. Scoliosis in Inflammatory Conditions of the Spine

Scoliotic deviations are also observed in association with arthritis and tuberculosis, in lues, osteomyelitis, or other affections of the spine. Such conditions must be discussed as symptoms of the greater underlying cause under the proper pathologic headings (Plate XXV, 4).

8. Scoliosis in Tumors of Spine or Cord

Sometimes tumors of the spinal column, or tumors of the spinal cord result in scoliosis; the latter often by causing spastic contractions of the musculature of the thorax, the former by causing a scoliotic attitude of defense against root or pressure pain. One such case of spastic contracture was observed by the writer. It was a case of very diffuse glioma of the cord producing unilateral spastic contractures of the muscles of the back, so that a total scoliosis of the spine resulted. In these contractural forms of scoliosis one finds a remarkable lack of rotation.

9. Scoliosis in Tabes and Syringomyelia

Lateral curvature of the spine is occasionally seen in tabetic afflictions of the spinal column and in syringomyelia. In the tabetic arthropathies the deformity is a true collapse type. In syringomyelia the condition may be due to contralateral paralytic conditions similar to the rare forms of scoliosis seen in tumors of the spinal cord (Plate XXV, 6).

10. Scoliosis and Trauma

Occasionally scoliosis is observed to develop so closely upon trauma that its relation to the latter cannot very well be ignored. Quite a number of cases of traumatic lesions of the back develop lateral deviation (Goecke[51]). Probably the majority of these are crushes or fractures of smaller portions of the vertebral bodies and their processes. Often such fractures cannot be distinguished in the x-ray picture and then the scoliosis remains the only visible objective symptom. The posttraumatic lateral deviation of the spine which develops some time after the trauma belongs in the same category with Kümmell's posttraumatic kyphosis (see Chapter on Traumatic Deformities of the Spine).

a. **Dorsal.**—Traumatic scoliosis of the dorsal spine often follows compression fracture of the 6th to the 9th dorsal vertebra. In Goecke's[51] series these scolioses were, without exception, right convex. Because of the close connection of the dorsal vertebrae with the thoracic cage, the curves resulting from spinal injuries in this region are more frequently arcuar than angular; the angular curves are more common in the lumbar section.

b. **Lumbar.**—Most of the cases of traumatic scoliosis in the lumbar spine are due to infraction of the 5th lumbar vertebra. In view of the great variety in anatomic contours and the numerous congenital asymmetries of this vertebra, the diagnosis of traumatic scoliosis, due to fracture of this vertebra, must be made with great care. One can be sure of it only when a callus or a fragment can be demonstrated. Fracture of the arch of the 5th lumbar is also difficult to diagnose because of the frequent anomalies or developmental arrests peculiar to this region.

It is not uncommon to find a posttraumatic scoliosis developing instead of a kyphosis, after injuries to the bodies of the lumbar spine.

c. **Changes in Intervertebral Discs.**—The lumbar spine representing a spring erected upon the pelvis has its elastic properties often overtaxed by injuries, so that the articular discs are no longer able to neutralize the jar or shock coming from above, and structural changes in the disc follow (Frey[46]). Degenerative changes of the disc result not infrequently in the shrinkage or even the disappearance of the disc. The asymmetrical position in lumbar scoliosis may often be considered as a defense attitude which later becomes compulsory and the scoliosis becomes established. In the same manner injuries involving the dorsal spine lead, according to Frey, often to a right convex scoliosis, the 11th dorsal being the one most predisposed to infraction and lateral deviation.

11. Empyematic Scoliosis

This is a true contractural, inclination type. It occurs in an entirely passive manner from the pull of the empyematic scar, and from the absence of lung pressure on the afflicted side, producing a curve with the concavity to the side of disease, with very little rotation. That it is not a weight-bearing deformity, though undoubtedly influenced by upright position, can be seen from the fact that it often develops in recumbency. Nevertheless, it is insidious in its development, often with a considerable period of latency. On the other hand, it must be pointed out that not all empyematic patients acquire scoliosis, so that a superinducing factor must be assumed.

12. Paralysis in Scoliosis

Spastic paralysis due to lateral curvature of the spine is very uncommon. Ridlon[116] reported two cases in 1916 (both congenital scoliosis), and Kleinberg[81] describes a case of congenital scoliosis with malformation of the vertebrae of the dorsal spine, complicated by spastic symptoms.

In the writer's series there were four cases of spasticity complicating congenital scoliosis. The most instructive case was that of a young girl of fifteen, who showed a marked high dorsal curvature with wedge formation. The patient was put in extension and while under treatment developed a rapidly increasing spasticity of the lower extremities. This was relieved by laminectomy and the patient made a complete recovery. At operation a sharp kink of the posterior surface of the vertebral bodies was found at the boss of the curve with a ledge pressing against the lateral and anterior surface of the spinal cord. In another case, that of a girl of sixteen, also with a high dorsal congenital curvature, spastic symptoms had made their appearance shortly before admission to the hospital and became rapidly worse during recumbent treatment. In this case, also, a laminectomy was performed. At operation there was found at the concavity of the curve at the level of the 2nd dorsal vertebra, a sharp ledge pressing against the spinal cord. The latter did not pulsate below the stenosis and was visibly compressed at this point. After the removal of the bony obstacle, and enlarging the spinal canal, both laterally and anteriorly, the cord again assumed normal dimensions and pulsation began to appear (Plates XXVI, 1, 4, and XXII, 3). Recovery followed.

In these cases it is difficult to account for the long latency of symptoms of spasticity as well as for the remarkable suddenness of their appearance.

In cases of high cervicodorsal curves of extreme degree, the writer observed symptoms of root compression of the brachial plexus (tingling, shooting pain), in connection with increased reflexes of both upper and lower extremities, from crowding of the spinal cord (Plate XXII, 1).

IX. THE DIAGNOSIS OF SCOLIOSIS

1. Technic of Examination

a. **History.**—Familial traits and points of heredity bearing upon congenital deformities, especially those of spine and thorax, must be brought out in the history as important and significant.

Next, it is of interest to ascertain the particular type of anatomic build existing in the parents or the family as a whole. Static instability or disalignment, such as flat feet, knock-knee, etc., or visceroptotic habitus often become of significance as they allow conclusions as to the inherited systemic propensities of the patient. The data concerning the patient's early years should prominently include a nutritional history. Even if no definite rickets can be established it may contain other important points of information.

PLATE XXVI

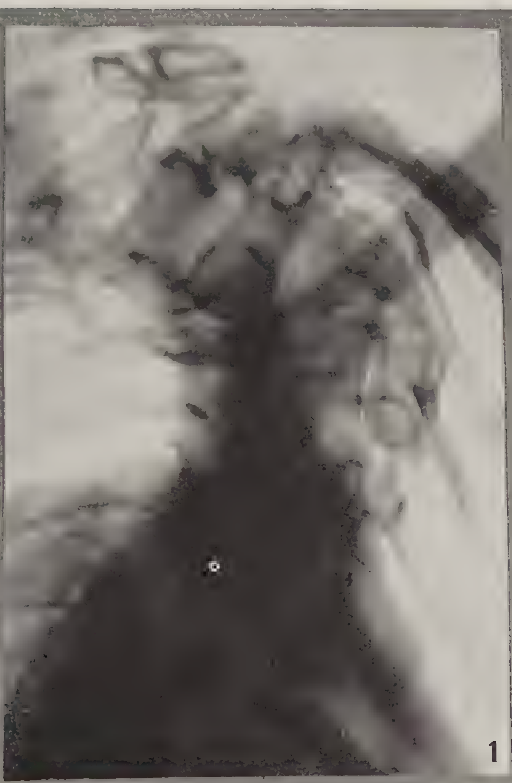
Fig. 1.—Congenital cervicodorsal scoliosis. (See patient in Plate XXII, Fig. 3.)

Fig. 2.—Schulthess' scoliosis recording device.

Fig. 3.—Beely's cyrtometer.

Fig. 4.—Findings at laminectomy of Fig. 1. (Note angulation and compression of cord.)

Fig. 5.—Trunk bending apparatus of Schulthess.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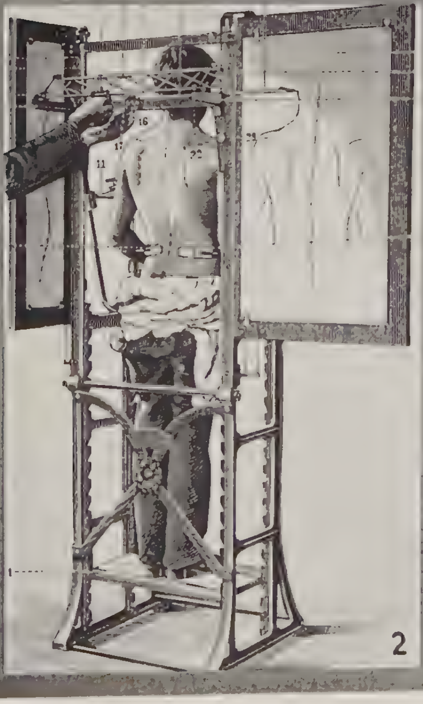
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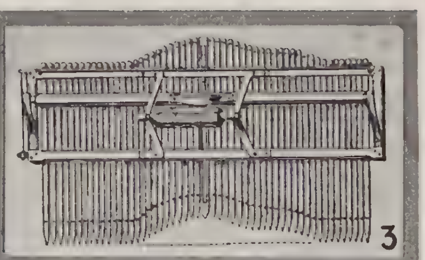
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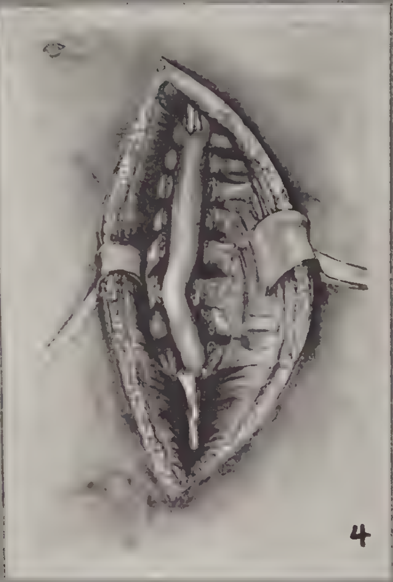
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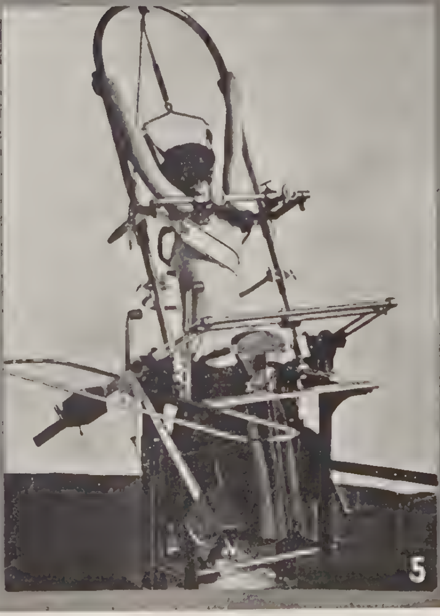
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PLATE XXVI

Details of growth are next of interest; ascertain, if possible, whether there was the proper proportion in development of height and weight. Febrile, especially contagious diseases, should be inquired into as they often determine the degree of individual resistance. Disturbance of the respiratory tract, including tonsillar and adenoid hypertrophies, should be noted. One must go carefully over the habits of the child in the first years of life, its physical activity, stableness of the nervous system, its need of sleep and recuperation. The following years often develop certain tendencies and attitudes of relaxation, slouching, slumping in walking and standing, etc. In older children be careful to cover in the history the periods of intensive growth, between three and five, and later, the years up to the beginning of puberty. An unusually rapid rate of growing should always be considered as a factor unfavorable for the steady and uniform physical development.

b. Present Illness.—As the history of the deformity is elicited from the parents, information is usually volunteered as to the time when it was first noted. Be careful to ascertain whether the first signs of the deformity, as they are brought to the attention of the parents, were secondary signs of disalignment of the trunk, such as the high hip or the high shoulder, or direct signs of the developing curves. Trunk disalignment develops only after the curve has been in existence for some time. Learn whether the deformity developed slowly or rapidly, whether or not it was accompanied by subjective symptoms, such as pain, fatigue, tire, etc. It is often associated with a noticeable deterioration of the general condition, or with signs of listlessness, irritability, nervousness, tire, and increased desire for rest and sleep.

c. Physical Examination.—The patient is examined completely undressed except for a loin cloth. The examination of the whole figure must precede the investigation of the curves. Examine the body first from behind, the patient standing. Notice first the alignment from the bottom up, so to speak, always having an eye for the relation of the body to the line of gravity erected upward from a point between the heels. Ascertain first any static disalignments of the lower extremities: valgus deformity, knock-knee, etc., which are liable to produce obliquity of the pelvis; ascertain whether the pelvis is, or is not, in horizontal position, and whether it is truly aligned over the supporting surface of the feet. One next turns his attention to the trunk and shoulders, and determines the alignment of the trunk and shoulders over the pelvis, to find whether or not there is a tilt of the trunk as a whole, to one side or the other. Check the position of the shoulders: are they even, are the shoulder blades arranged at corresponding levels? Does head and neck occupy a symmetrical position over the shoulders?

The contours of the trunk are next taken into consideration. The areas lying between the side of the trunk, pelvis, and the overhanging arm, the so-called waist triangles, should be symmetrical. If the body is aligned asymmetrically and tilts over to one side, the waist triangle on this side is seen to open downward, so that the arm hangs loose by the side of the body. Next the curve itself is investigated: note its situation and its extent, the position of the apex of the curve, its perpendicular distance from the line of gravity. Note next the degree of rotation of the thorax, manifested by the elevation of the ribs, or in higher curves by the concomitant elevation of the shoulder blade which is carried upward and backward. In low curves, as the body tilts to one side, the apex of the waist triangle is abolished while it is deepened on the opposite side. This gives the impression of the so-called higher hip on the side of the concavity even though both pelvic halves occupy the same horizontal level. To bring out more clearly the feature of rotation, let the patient now bend forward with arm hanging down vertically until the head just disappears in front of the shoulder line. Even a slight rotation deformity will become manifest, and can be felt by sweeping the palm of the hand lightly over the posterior aspect of the thoracic cage, as a sharper curving of the ribs on the convex side. Next we establish the mobility of the spine and thorax in the region of the curve as well as above and below. Test the active mobility by making the patient carry the trunk through all ranges and planes of motion. Note restrictions in different sections. Test the passive mobility of the trunk. Ascertain the degree of rigidity of the curve by diagonal pressure in direction of derotation and lateral correction, one hand upon the convex side gibbus behind, the other upon the concave side costal prominence in front. Is the feel of the curve springy and elastic or hard and unyielding? What is the pliability and elasticity of the ribs and how does it compare with that of the spine?

Examine the muscles of the back. Look for rigidity and contracture. Not only the longitudinal musculature but also the transverse one, i.e., latissimus dorsi and trapezius must be given consideration.

Then the patient is turned around and examined from in front. Note again the alignment of the body over the pelvis, and that of the pelvis over the feet; note the prominence of the ribs anteriorly on the concave side, the position of the sternum, the outlines of the waist triangle on both sides; note the position of the anterior superior spine; the degree of rotation of the pelvis, tilt and inclination.

Then, with the patient lying supine the outlines of the viscera of the thoracic cage and abdominal cavity are determined. Signs of displacement of heart, or of the visceral organs are established. The respiratory index is then taken by measuring the respiratory excursion at the level of the mammillae, at the lower costal angle, and over the umbilicus. The excursion of the lungs is also examined by percussion and auscultation.

The rotatory alignment of the body is established by comparing the situation of the anterior superior spine with the line connecting the centers of the shoulder joints on one hand, and the line through the anterior and posterior costal gibbus on the other. Note also the position of the hip joint. At the site where the pelvis is rotated forward the hip joint in upright standing is outward rotated, whereas, on the opposite side, its rotation is inward. The patient is told to rise, and one next examines the trunk for extensibility and the distribution of body weight. To examine for extensibility the patient's head is placed in a Glisson sling and traction is made equal to one-half of his body weight, so that approximately all weight is relieved from the lumbosacral junction. The normal extensibility of the spine, under these conditions, measured from the 7th cervical to the sacrolumbar junction, is about 2 per cent of the length of this section. It was found considerably higher in paralytics and in habitual curves, especially after they had undergone vigorous treatment by extension (Steindler[145, 146]).

Testing for the distribution of body weight is best done upon a twin scale (Plate XXIX, 3). It can easily be established that on the side of the tilt or overhang a considerable surplus of body weight is active. The anteroposterior distribution of the body weight should also be ascertained. In the normal posture a considerable excess of body weight is borne by the ball of the foot; this relation may be reversed in cases of scoliosis with considerable rotation and kyphosis.

The general examination of the patient should never be neglected. This includes the examination of the upper air passages, of the viscera, of the abdominal and thoracic cavities; it includes, of course, also the examination of urine and blood, and in older patients, of the blood pressure.

2. Points Bearing on Prognosis

From the data gained by such an examination one should also be able to become informed on the following points bearing upon prognosis and treatment of the condition: Is the curvature developing more rapidly or more slowly, that is, is it more malignant or more benign? To what degree is it met by the patient's individual resistance? Has the deformity progressed to contractural or even ankylotic state or is there still some incomplete muscular control? Have the secondary curves developed? Do the sections above and below the primary curves show mobility, and to what degree? Is the rotation deformity more extensive in comparison with the lateral deviation? Are the long muscles of the back contracted or relaxed, are they atrophic or well developed? Has the respiratory function of the thoracic cage suffered as the result of the spinal deformity? What is the condition of the muscles of the abdominal wall? Has the loss of thoracic and abdominal balance impaired the health of the patient? And are secondary signs, such as insufficiency of the circulation, respiratory embarrassment and disturbances of the digestive tract evident?

It is during the primary examination that an answer should be found to all or most of these questions in order to appraise the possibilities for improvement and to lay plans for treatment and management of the conditions.

3. Scoliosis Records (Plate XXVI, 2, 3)

The keeping of graphic or pictural records is indispensable in appraising the progress and efficacy of the treatment.

The most thorough are the records obtained by the measuring apparatus of Schulthess[137] in which tracing of the lateral and rotatory curves are projected in pantographic manner (Plate XXVI, 2); Beely's cyrtometer gives good records of the rotation at different levels (Plate XXVI, 3). The method of Freiberg[47] of outlining the curve on a celluloid plate hung over the back and carefully aligned, and of keeping a uniform record by drawing the tracing obtained to scale, is both simple and efficient. The writer uses photographic records, which, objections to the contrary, can be made reliable if consistently taken under uniform conditions of alignment (posture), size, distance, and lighting. In addition to this, the distributon of body weight, over right and left, and anterior and posterior halves is ascertained by twin scales.

X. PROPHYLAXIS OF SCOLIOSIS

Timely prophylaxis of scoliosis means prevention during prescoliotic stage and not later. Therefore, earliest recognition is a most essential prerequisite of prophylaxis.

1. Congenital Scoliosis

While one cannot properly speak of a prescoliotic stage in congenital scoliosis, nevertheless, it must be considered that there is a long period of latency during which the spine is able to maintain its equilibrium against the odds of asymmetrical weight bearing. Consequently early recognition of the deformity determines the successful checking of its progress. Many of these congenital deformities appear at first in the light of postural anomalies and asymmetries, and can, at this stage, be influenced by systematic muscle training and scolosis gymnastics. A great deal, of course, depends upon the location of the congenital anomaly. Wedge formation, or other anomalies in the lower spine offer a less favorable outlook for maintenance of balance than those located at a higher level.

2. Rachitic Scoliosis

In the rachitic type of scoliosis we are in a better position to practice prophylaxis. It is here where one may practically speak of a prescoliotic stage as already described under the pathogenesis of the condition. The asymmetries acquired during this stage are faulty attitudes in positions of rest, such as forward flexion in sitting or lateral bend in children carried upon one arm. Here, also, the deformity remains functional or attitudinal for a considerable length of time before it enters into the structural stage. One must keep in mind that the rachitic scoliosis is not primarily an expression of muscle insufficiency but rather of the relaxation of the costovertebral junction and of the intervertebral articulations, due to the softness and increased pliability of the spine.

In the prophylaxis of the rachitic scoliosis the general antirachitic régime is the principal factor. Next, the local treatment of the musculature by massage and manipulation insures best the stability of the spine. Children with posterior deformity should not be encouraged to sit up too soon and should be carried on a board or plaster bed rather than upon the arm.

3. The Prophylaxis of the Habitual Scoliosis

Of all types the habitual or idiopathic scoliosis has always received the greatest attention, but the interest manifested in school children between the ages of eight and fourteen is belated. One must remember that a child which assumes an asymmetrical attitude, and from which it is being aroused with greater and greater difficulty, is already a scoliotic child. The fight against scoliosis of the habitual type, therefore, should begin before school age, the same as the prophylaxis of the rachitic and other types. According to the best observations the influence of the school is that of an accentuating and aggravating element, but it is not in itself a causative factor.

In examining a number of school children Scholder[136] found 20 to 30 per cent showing functional scoliosis as a result of faulty posture assumed by the child during or before school years. For the habitual type of scoliosis the critical period is that of rapid growth between the third and fifth years, and it is at this time when prophylactic measures should be instituted. Postural exercises should be taught and other general measures taken to prevent the occasional faulty attitude occurring at this age from becoming habitual. Between the ages of eight and fourteen there must be a proper supervision of posture during school hours and, still more important, the shortening of the school periods, and the introduction of appropriate physical exercises of general character must be given serious consideration.

4. Prophylaxis of the Paralytic Scoliosis

Prophylaxis of the paralytic scoliosis is difficult because of the long interval of complete latency which exists between the onset of paralysis and the first appearance of scoliosis. In cases of extensive paralysis of the lower extremity it is best to reckon with the possibility of subsequent scoliotic deformity so that precautionary measures may be undertaken as a matter of routine. It is much easier to recognize a general weakness or paralysis of the back muscles than to detect unilateral differences in muscle strength. However, it is just this situation that so often leads to paralytic scoliosis. Symmetrical paralysis of the muscles of the back or of the abdomen usually results in anteroposterior curves, while the lateral curves more often develop from unilateral or unevenly distributed paralysis. It is well known how irresistibly this type of deformity progresses. Consequently even the slightets suspicion of weakness or asymmetry of the back indicates definite measures of prevention. In no deformity of the back does the progress show such tragic rapidity and such bitter extremes as in the paralytic type.

XI. THE TREATMENT

1. Historical

The evolution of the methods of treatment for curvature of the spine is interesting and significant enough to merit a short résumé.

After the introduction of the iron cuirass of Paré[107] in 1575 the history of scoliosis treatment remains silent for almost a century, until in 1641 André again took up this problem. One may date scoliosis treatment of the more modern type from the middle of the nineteenth century. At this time the myotomies of Guerin[52, 53] made their first appearance as a systematic procedure. At the time when Lorenz[87, 88] wrote his treatise on the lateral curvature of the spine, in 1886, steel corsets and braces were in vogue, although their corrective effect was denied by Lorenz. In 1878, however, Sayre[125, 126] introduced his plaster jacket, claiming for it only support and not correction. Then followed various types of supporting apparatus, the felt corset, the gutta percha corset and others, all applied in suspension. Later attempts were introduced to correct the curvature by lateral pull or pressure. To these measures belong the swing of Nebel,[103, 104] the frame of Bradford,[20] and other contrivances, all of which provided for the correction of deformity under lateral pressure. Such were the preliminary steps leading to the method of forced reduction devised by Delore,[27] later taken up by Calot,[24, 25] Redard[113] and others, who applied to the correction of lateral curvature of the spine the principles that had been in use previously for tuberculous deformity. Although in the development of scoliosis treatment the corrective jacket of Sayre marks a very important event, yet it was not without its critics. Drachmann[30] compared it very unfavorably with the correction obtainable by suspension, although it was generally conceded that the plaster jacket had some checking effect upon the progress of the disease. The remarkable advance in the apparatus technic due to the work of Hessing gave the brace treatment of curvatures of the spine additional grounds. Dolega,[29] Roth[121] and many others obtained and reported favorable results by the use of these braces. Still the brace treatment also had its adverse critics; especially was it claimed that the brace had no effect upon correction, and very little upon maintenance (Judson[73]). Opposition to casts and corsets arose also from other reasons: one was the atrophy of the musculature and the restriction of the development of the thorax (Redard[113]). Dollinger found that the scoliotic spine one year after plaster treatment was so soft that it was unable to hold itself and became very prone to collapse, much more than it was before. This was also the view of Vulpius[153] who restricted the use of plaster to severe cases which were already more or less rigid. There was further opposition to the brace on the grounds that it restricts respiration, and that it, therefore, was especially obnoxious in girls in whom the breathing mechanism is more of the thoracic type. It was considered an error to suppose that a well-fitting corset was able to stop the progress of deformity, and many warned of the indiscriminate use of braces (Hussy).

On the operative side there was also a rather fitful and sporadic development of methods. The operative attempts of Guerin did not remain without followers even in more modern days. In this respect it is of interest to follow Krukenberg's conception regarding the effect of asymmetrical contracture of the psoas muscle on scoliosis. Believing that the psoas muscle becomes contracted, and that it accentuates the existing deformity, he included in the treatment of severe lumbar scoliosis the tenotomy of this muscle. From the same point of view the tenotomy of the scaleni in the treatment of cervical scoliosis was recommended.

To the older operative methods also belong the rib resections. Bergmann resected the costal prominences in two cases (1889) and six years later did his first subperiosteal resection of the 3rd to the 9th rib with apparently good cosmetic results.

The modern treatment of scoliosis was rationalized by Hoffa[61] when he emphasized as the three basic principles: mobilization, redressment, and stabilization, and demanded for each its proper place in the scheme of treatment. Mobilization was to be carried out by gymnastics, active and passive movements, which not only involved the back but also the extremities and the respiratory mechanism. In other words, a general plan of strengthening and developing the musculature was adopted. Soon, a certain radicalism developed in this line; one side laid more emphasis upon the gymnastic phase of treatment, another more upon the redressment. Redressment was now attempted by pressure in diagonal direction instead of longitudinal traction as before. The machinery designed by Hoffa, Schede,[133] Hübscher,[66] and Dolega[29] and finally the apparatus of Schanz[129] served the technic of manual redressment principally in the standing position, while the apparatus of Hoffa and Barwell[11] serve the same end in sitting position of the patient. With the machines of Nebel[103, 104] and Zander,[158] this was accomplished in horizontal or oblique position. Finally a number of apparatus such as those of Beely[12] and Lorenz[89] and others redressed the patient in recumbent position, all planned on the same general principle, namely, the forcible redressment of the deformity by either tangential or diagonal pressure.

Since it was then agreed that redressment by direct pressure was necessary, the question had to be decided what its mechanical effect was upon the spine and whether or not it could be demonstrated experimentally. Wullstein[157] investigated the problem of the effect of forced extension and forced redressment on the cadaver, and found that the intervertebral discs of the wedge vertebrae, on the side of concavity became enormously stretched to double or treble their thickness while maintaining their original thickness on the convex side. The same thing was found in the intercostal spaces which, too, were enormously stretched on the concave side and flattened on the convex side. Mechanically speaking, therefore, there was no real straightening of the spine accomplished but rather a straightening of the whole spine over the convexity of the original curve as fulcrum. These investigations are of great interest because they demonstrate the enormous resistance of the original curve and the inclination of the adjacent movable section of the spine to yield to passive redressment. It was also found by Wullstein that forcible detorsion was possible by flattening the costal prominence and by arching the flattened portion of the ribs, and in the same manner he was able to produce an untwisting of the pelvis. However, in all his experiments an excessive force was necessary to bring about appreciable changes, a force greatly exceeding any amount which could be applied safely upon the living.

We see, then, the general principles of scoliosis treatment as formulated by Hoffa recognized at the end of the nineteenth and at the beginning of the twentieth century. Only, according to individual experience and inclination some surgeons laid more stress upon the mobilizing phase, others upon the corrective side, while others, again, contented themselves with the problem of fixation, giving only scant attention to forcible measures of correction.

It seems, however, that none of the methods presented was able to justify itself by late and permanent results; they failed, not because of the inadequacy of the principles involved in the correction of the deformity, but rather because of their inability of maintaining this correction.

2. Classification of Modern Methods of Scoliosis Treatment According to the Outstanding Principle

a. Mobilization in Scoliosis Treatment.—To begin with, this principle of increasing the mobility of the spine as a whole, by gymnastic methods is included in practically all methods and used as part of their general plan. Hoffa, in teaching special gymnastics applicable to the case of scoliosis, emphasizes the development of the muscles as the principal scope, believing that the more movable the spine could be made the better for the ultimate correction. He advocates such exercises as stretching by active correction or active redressment, swinging, side bending, falling out exercises, etc. A similar type of exercise is that advocated by Estor,[37] who adds to it passive mobilization by apparatus.

Klapp,[76] observing the characteristic gait of quadrupeds, used the effect of the quadrupedal gait upon the pelvis in his creeping exercises, a method which has gained general recognition and had the hearty approval of Schulthess. Such mobilizing exercises, whether they be of the creeping type or in apparatus as devised by Schulthess, bring about the best possible degree of mobility in the lumbar spine for the indirect benefit of a primary curve situated at the higher level. Directly this mobility is utilized to produce the counter curve at the lower level.

Truslow[149, 150] developed in great detail a method for the development of the natural muscular support of the spine upon the principle of minimum erect weight bearing.

The rationale of mobilizing treatment is always the development of a natural safeguard against recurrence of deformity after correction. The active exercises are so devised as to develop, in the most efficient way, counter

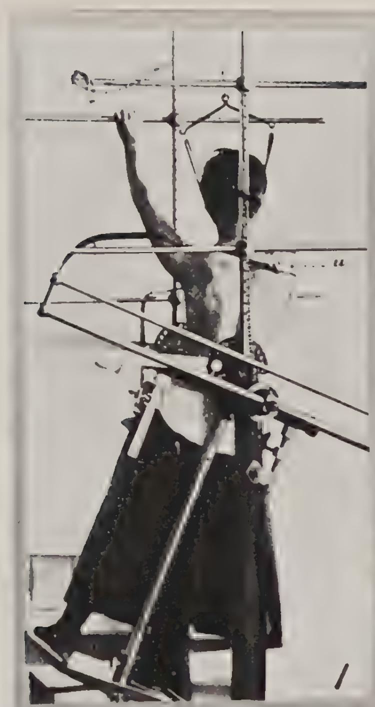
PLATE XXVII

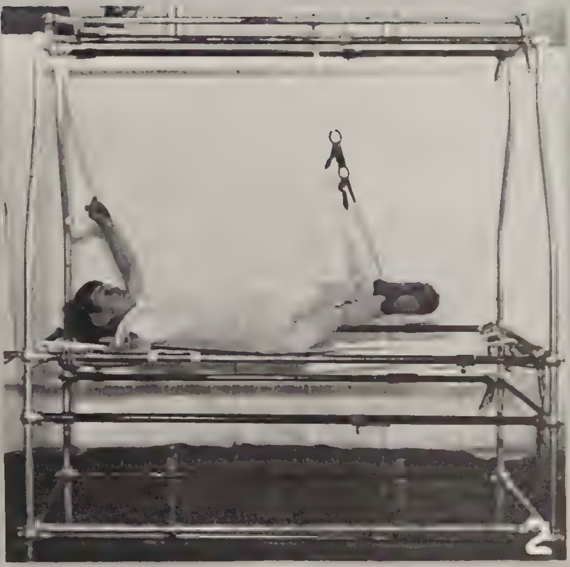
Fig. 1.—Schulthess' lumbar spine mobilization apparatus.

Fig. 2.—Armin Klein's method. (See text.)

Fig. 3.—Abbott forcible correction cast.

Fig. 4.—Application of Abbott cast.





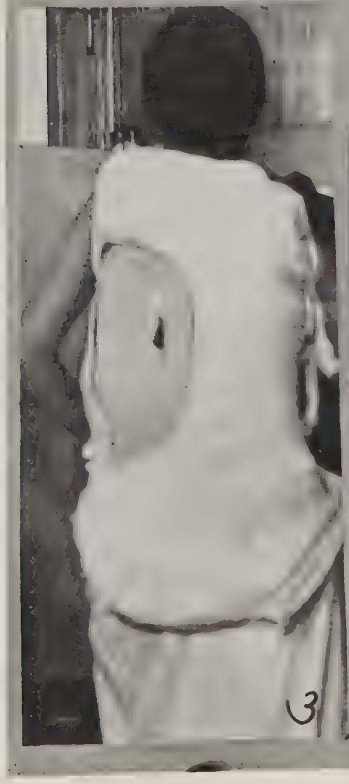


PLATE XXVII

curves in the cervicodorsal and lumbar regions. Both the movement of the pelvis and the movement of the shoulder girdle are called upon to bring about the increased mobility necessary for the development of these counter curves.

Exercises on simliar lines were devised by Estor[37] and Roederer in France in form of sallies, falling out exercises, ''spring sitting'' exercises, pendulum swinging exercises, many following the suggestions of Schulthess and others. No minute description of these exercises is necessary as they are self-explanatory and can easily be selected by an intelligent teacher. They are chosen with regard to their ability to produce not only spinal relaxation, but also postural correction, deep breathing, and control of the abdominal muscles. They are all self-corrective in that they call upon an active and voluntary muscle control. No matter how asymmetrical a deformity, the treatment always should include a set of symmetrical exercises for the standing as well as recumbent positions, including exercises for the abdominal muscles and the muscles of the hips (Drew[33]).

b. Mechanotherapy.—The principle of mobilization of the spine is further realized by mobilizing apparatus (Mechanotherapy). It is a helpful adjunct to the gymnastic type of treatment, which it is not, however, intended to replace. Its greatest development it owes to Schulthess,[139] who devised a series of pendulum apparatus, each one with a particular effect upon the spinal movements. Some are devised for mobilization of hip and lumbar spine, others for the shifting of the shoulders, for the elevation of the shoulder, for derotation and detorsion, for elevation and depression of the ribs, and for flexion and extension movement of the thorax, etc. (Plate XXVI, 5) (Plate XXVII, 1). Another type of apparatus somewhat similar in construction is that of Krukenberg,[82, 83] constructed on the principle of the so-called Zander[158] machines. Their function is to produce, by passive movement, a greater range of mobility of the spine. In doing so they overcome structural, muscular, or ligamentous resistances, which have become established during the development of the scoliosis.

c. Suspension.—The principle of suspension is also a factor in mobilization of the spine. It had already been used by Sayre[125, 126, 127] in his application of the plaster jacket, being conceived with the idea of correcting the spine by extension from head to hip. This, however, as Wullstein[157] has shown in his experiments, is only possible by an excessive and impracticable degree of force. Furthermore, Hoffa[63] and Lorenz[89] observed that the detorsion by extension was only apparent. There was no doubt that a certain stretching and lengthening of the spine could be obtained by suspension with reasonable force, but it remained doubtful whether this extension of the spine actually concerned the scoliotic portion, or did not rather become effective upon the less rigid nonscoliotic portions of the spine. At any rate extension as a means of correction has never given satisfaction and is now used only as an accessory means of fixation during the application of plaster casts.

3. Modern Combined Corrective Methods

Correction by combined methods of redressment and immobilization goes back to Schede,[133] who expressed himself rather skeptically upon the curability of scoliosis in the anatomic sense. From the beginning of this century the ingeniously devised and highly perfected methods of Wullstein[157] Schulthess,[139] Bradford,[20] Lovett,[91, 92] Kleinberg,[80] Klein,[77] and others, have dominated the field of scoliosis treatment. All these represent combined methods of redressment and retention. Such a redressment may be carried out in Sayre's plaster jacket either in upright position or horizontally, in supine or in lateral position. Taylor[148] applied his jacket with the patient sitting; Calot[25] makes his redressment in prone position. Combinations of such redressments and extension are used by Schanz,[129] who extends his patient from head and hip or feet, in vertical or standing position. Extension combined with lateral traction is used by Wullstein, the spine being first relieved of the superincumbent body weight and then correction of the curve being accomplished by the application of pressure or pull.

a. Method of Klein.—The choice of the position suitable for redressment was greatly influenced by the extensive investigations of Lovett regarding the effect of forward flexion upon the pliability of rotary curves. Upon this basis, A. Klein,[77] of Boston, developed a treatment representing a combination of the exercise and corrective plaster jacket methods. After preliminary treatment by mobilizing exercises a corrective plaster jacket is applied. The patient is in supine position, the pelvis is rotated away from the direction of the dorsal curve, and the shoulder girdle is rotated in a direction opposite to the twist of the pelvis, that is, toward the convexity of the dorsal curve, so, if the patient has a right dorsal, left lumbar scoliosis, the shoulder would be turned to the right, while the hips are turned to the left. This twist of the body is forced until the transverse axis of the pelvis and the transverse axis of the trunk stand at right angles (Plate XXVII, 2). So, to the pathologic element of deformation in the dorsal section, Klein adds the physiologic element of rotation in the opposite direction. Because there is no independent rotatory movement in the lumbar spine, the pelvis, being rotated opposite to the dorsal rotation, imparts this rotation through the lumbar spine to the dorsal column, thereby acting as a very powerful lever for the detorsion of the dorsal curve.

b. McKenzie-Forbes.—In his detorsion method McKenzie-Forbes[44, 45] makes use of a similar principle. The correction is carried out by rotating shoulder and pelvis against the trunk. The thorax is rotated from the shoulder in the direction of the scoliotic curve, imparting the derotating force through the ribs upon the concave side; as Forbes expresses it: superimposing a physiologic rotation of the reverse order upon the pathologic rotation of the curve. This principle is usually little understood, but in the light of the newer conceptions of the mechanism of scoliosis it appears sound and is full of interest.

By the usual derotating methods the thorax in a case of right dorsal curve would be twisted opposite to the pathologic rotation, that is, in this instance, counter-clockwise. Such an attempt, however, would only increase the flatness of the convex side rib in front, bringing the sternum more to the side of the concavity, and it would further distort the thorax by increasing still more its convex oblique diameter. It is clear that the anterior flatness of the convex side rib cannot be rounded out unless a point of application is found over the sternum or over the concave side ribs in front. When, however, the shoulders are rotated in the direction of the thoracic curve, then the flattened convex side ribs are recurved in front, the pull is transmitted through the sternum to the concave side ribs in front, flattening the anterior concave side costal prominence. Then, posteriorly, the flatness of the concave side rib behind is converted into a convexity, so that the force applied to the sternum in the direction of the original rotation finally accomplishes a curving or curling of the concave side ribs. This, again, is supposed to have the same rotating effect upon the vertebrae on the concave side, that the convex side rib originally exerted upon the spine on the convex side, only, of course, in opposite direction. According to this conception the pathologic rotation becomes actually superimposed by a physiologic rotation of the opposite order, provided, of course, that such rotation can be effected in a tangential course along the bodies of the ribs as provided in the plan of this treatment. The mechanical premises are, that the ribs on the concave side which are now curled up against the vertebral bodies, are actually able to exert a leverage action upon bodies and transverse processes on their side, so that a counter-rotation to the concave side results. The only flaw in this arrangement seems to be the elasticity of the ribs which we believe does not allow adequate transmission of force applied from their anterior end. It does not seem probable that this extensive counter-rotation actually takes place to the desired degree and exerts its derotating force upon the vertebrae; but this is not because of any fault in the mechanical arrangement but simply because the rotating force is absorbed by the elasticity of the ribs and so, does not reach their posterior portions on the concave side where it is needed to effect the psysiologic counter-rotation.

c. The Abbott Treatment.—No other treatment in the last decade has aroused the interest and has enjoyed the reception than the one introduced by E. G. Abbott[186] in 1911. He described a new technic of application of corrective plaster jackets based upon the assumption that correction and overcorrection in an anatomic sense was possible, at least, for moderate degrees of structural deformity. Such an overcorrection was to be considered complete when the diagram showed that the lateral deviation, as well as the rotation, was reversed from the original deformity into the converse one. The method is no longer in general use and, therefore, it may seem unnecessary to go too far in the description of the technic. The principle involved, however, covers not only this, but also other methods of forcible correction.

That the method has failed was certainly not the fault of the technic. It must be said to the credit of Abbott that his technic was most carefully worked out and carried through with a great deal of determination and patience (Plate XXVII, 3, 4).

If a method has failed in principle, it is more than ever necessary to give the reason for failure instead of stating the mere fact.

The principle of this treatment was overcorrection by corrective plaster casts applied in position of forward flexion. This feature is taken up from the experiments of Lovett.[91, 94] He showed that flexion diminishes lateral mobility and rotation in the lumbar region and that extreme flexion in this region blocks both lateral bending and rotation; in the dorsal region, however, it is the hyperextension which diminishes lateral motion and rotation, and extreme hyperextension locks the dorsal region both against lateral bending and rotation. He thereby proved that the positions of hyperextension in the dorsal and hyperflexion in the lumbar region, are unfavorable for correction. There is, however, no evidence to show that either the rotatory or the lateral movement of the dorsal spine are only possible in forward flexion, nor that such movements in the lumbar spine are possible only in the hyperextended position. This touches an eminently practical point. If a very strong forward flexion must be used, it entails a most trying and severe feature in the application of the corrective cast. On similar premises the treatment of Galeazzi is founded, except that he applies his cast in standing position and that the forward flexion of the body is not so extreme.

It is largely because of the great inconvenience arising from the forward flexed position that Abbott's method has been gradually abandoned as too severe and dangerous.

We know from kinesiologic studies that the dorsal spine displays a considerable rotatory amplitude in standing position; the best authorities (Fick,[40] Fischer,[41] Strasser,[147] Novogrodsky[105]) do not recognize that forward flexion alone, will, in the term of Abbott, open up the spine and make rotatory movement possible. The plan of the Abbott treatment is briefly as follows: overcorrection by the already described plaster jacket in forced flexion. When overcorrection is accomplished, a corset is applied in the same position, the efficacy of which is determined by a skiagram taken through it. The corrective posture is obtained by placing the patient in a sagging hammock, the flexion being increased by the weight of the body and by elevating the legs. Then the pelvis is fixed and corrective rotation and lateral bending of the trunk is carried out by straps or bandages. Heavy felt pads are applied and are constantly added to, during the corrective cast treatment through windows cut out over the concavities of the curve, back and front (Plate XXVII, 3, 4). When the corset is finally removed the patient undergoes vigorous treatment by exercises and massage. The method has found numerous followers. Still, Papadopoulos,[106] who is an adherent of Abbott's method of forced correction believes that the problem of the rigid structural scoliosis still remains unsolved and that the method will only cure cases which are hypercorrigible and easily reduced, and these on condition only, that the treatment be prolonged over several months and sometimes for years in order to allow anatomic changes to take place.

d. Galeazzi's Method (Plate XXVII-A).—R. Galeazzi utilizes a method of treatment which obtains a remarkable degree of correction of the rotation, much more than is seen with the Abbott treatment. The superiority of the procedure lies in the fact that derotation in the flexed position is very gradually obtained, without, however, direct lateral force being utilized as in the Abbott technic.

The corrective casts are applied in a special apparatus. In principle, the method as observed in his clinic at Milan is the following:

The patient stands on a small platform. His pelvis is fixed by two clamps above the greater trochanters. He then bends forward about ninety degrees placing his hands on two handles, while his shoulders are received by two other clamps. The platform he stands upon is built on a swivel so that it can be tilted sideways and rotated. The shoulder and hand support is attached to a second similar swivel, permitting similar adjustments. The levels of hip and shoulder ends of the machine may be raised or lowered at will. Furthermore, the distance between the two swivels may be made greater or smaller, accordingly effacing or increasing the lumbar lordosis or kyphosis.

The center of each swivel is then adjusted to coincide with the center of each curve. If there is but one curve, only the shoulder half of the machine is rotated.

The lumbar curve is corrected by a three-headed bandage similar to that used by Abbott. Then the pelvic half of the cast is snugly applied over sheet wadding. The straps are drawn tight, and the pelvis is rotated as far as possible in the sense of overcorrection.

Next the primary curve is taken care of. The shoulder half of the cast is now applied. Then the cast is cut out over the original curve. The three-headed bandage is applied firmly, and the shoulder is inclined against the convexity of the curve and rotated in the sense of the convexity (the principle of Mackenzie-Forbes). In such fashion, the correction of the primary curve is obtained.

Following this, both halves of the cast are united by plaster, and the clamps are easily removed. The cast is trimmed to below the greater trochanters and extends high at the shoulders. A window is cut over the concavity.

The cast can be applied in 10 to 15 minutes and is changed approximately every three months—successive casts continued for 18 to 36 months. A rigorous aftertreatment is instituted with the intention of developing muscles to hold the correction obtained.

The key to the corrigibility of the spine lies in the long preparatory mobilizing treatment which the patient first undergoes. Modifications of the

"Schulthess Shoulder-Shoving Machine" and Galeazzi's own apparatus are utilized for this purpose. Classwork in the gymnasium wherein creeping and corrective gymnastics are stressed, are integral portions of the preparatory mobilization. By the use of a machine identical with the cast application apparatus, the patient is gradually accustomed to the position of correction.

The treatment is severe and prolonged, but the correction obtained is most unusual. Correction apparently has been maintained by Galeazzi for a number of years. It remains, however, to be seen whether the ultimate maintenance of correction will be any less of a problem than in the other methods of forcible correction.

e. **Modifications.**—In the period which followed many modifications and combinations of the redressment method were practiced.

The alternation of the corrective jacket treatment with the gymnastic exercises for the development of the muscles is emphasized by Truslow.[149, 150] In the modification of Estor[37] and Broca[22] the method appears less severe but the principal factor, namely, the immobilization in hyperflexion and the overcorrection in this position, still remains the salient point. Galeazzi's method, mentioned before, is similar in technic to that of Abbott except for slight changes in the posture of the patient (Commisso[26]). Some of the Italian orthopedists (Commisso, Galeazzi) still adhere to the point that maximum flexion of the spine offers best opportunity for correction because it unlocks the intervertebral articulations for rotation and lateral bending.

f. **Reports.**—The claims upon which treatment by forcible corrections is based, are, first, that overcorrection is possible; second, that overcorrection necessitates forward flexed position; and lastly, that overcorrection so obtained could also be made permanent. It developed, however, in the course of time, that none of these claims could be substantiated.

From the report of the Scoliosis Committee of the American Orthopedic Association[142] of 1916 (Freiberg, Silver, and Osgood), it appeared that the amount of correction demonstrated did not justify the use of extreme force which had to be applied. No undoubted case of overcorrection of structural scoliosis had been served, which was attended by definite cure. It was felt that more correction in moderately severe cases could probably be obtained in flexion position, but that even this was brought about by a degree of force which must have approached the point of danger for the patient.

Calvé's[23] method accomplishes a compensatory rotation in the lumbar spine with the aid of the pelvis. The rotatory amplitude of the lumbar spine is very limited, and any forcible rotation of the pelvis immediately transmits itself through the lumbar spine in form of rotation. By rotating the pelvis in the opposite direction of the dorsal rotation, he imparts to the dorsal section a physiologic rotation in the opposite direction. One will note that this falls in line with the principle of Forbes[45] only that the latter attempts his derotation of the curve by applying the corrective force to the thorax

PLATE XXVIIA

The Galeazzi Treatment of Scoliosis

Fig. 1.—Galeazzi's apparatus for derotation of spine.

Fig. 2.—A. Patient before correction.
B. Same patient after correction.

Fig. 3.—A. Patient of 2A. Forward bending.
B. Patient of 2B. Forward bending.

Fig. 4.—X-ray of patient of 2A. Before correction.

Fig. 5.—X-ray of patient of 2B. After correction.

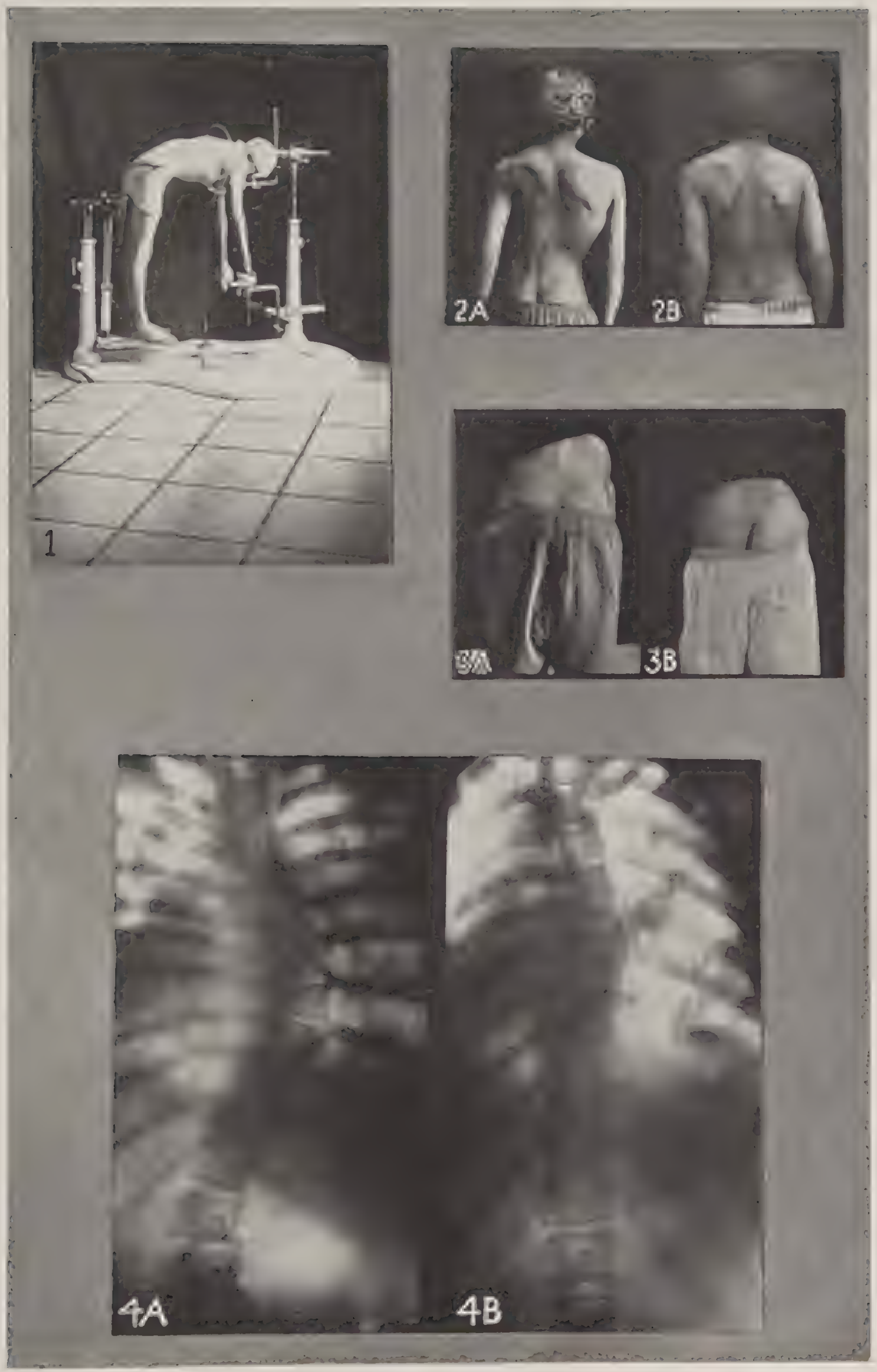


PLATE XXVII-A

instead of the pelvis. That this method is doubtful in its effect is because of the rigidity of the spine and the pliability of the thoracic cage, which has been mentioned before.

g. **Compensation Principle in Methods Named.**—The methods of Forbes, Calvé, Klein, and others, are all implicitly subservient to a principle of compensatory correction, that is, correction by the production of compensatory curves. This principle it seems was first recognized by Schede and it appears that, in the methods mentioned, it is being carried out incidentally, both in regard to lateral deviation and rotation. One may say that all methods which do not use sufficient force to actually break the rigidity of the original pathologic curve must take effect upon the more movable section, and that such an effect expresses itself in the development of counter-curves or counter-rotation. So much for the presupposition that a direct and immediate correction of the rigid curve itself is possible.

Next, is the question of the forward flexed position. This principle which is embodied in the more recent methods of conservative corrective treatment is based upon the classical investigations of Lovett, who applied his plaster jacket in prone position with the legs hanging down.

h. Lovett's Experiments and Compensation.—In his experiments on cadavers Lovett[93, 94] found that the effect of traction upon correction of the lateral curvature as well as of rotation is negligible. He found that lateral pressure gives only insignificant results, but, and this is the most important point, he also found that it was easier to displace the whole scoliotic section to one side than to straighten it. He found that manipulations which are to correct either torsion or lateral deviation seemed to take more effect above and below the original curve; he found that rotation on the convex side forward, increased the lateral curve and decreased rotation, while rotation on the convex side backward, decreased the lateral curve and increased rotation. Therefore, with decreasing rotation the lateral curve, at the same time, appeared increased and vice versa, by manual increase of the rotation the lateral curve was decreased. The practical conclusions of Lovett's were that the treatment must be different for fixed and rigid immovable curves. The fact that there is interposed between the two movable parts, the fixed and rigid scoliosis, makes it easier to displace the thorax en bloc than to correct the rigid curve. He further found that suspension makes very little difference and that redressment in the ordinary sense is much more likely to produce a lateral or translatory displacement en bloc and, thereby, to improve the general alignment. Here, we have conclusive evidence of the effect of passive redressment not associated with an extreme amount of force such as is used in the treatment of Abbott. This evidence is, that such a redressment is going to lead to development of counter-curves in the upper and lower movable sections of the spine. Above all things, then, we find in Lovett's investigations the experimental proof of the transmission of corrective forces applied to scoliosis, to the superincumbent and subadjacent portions of the spine. And this is the underlying basic principle of the treatment of compensation as practiced by the writer.

i. **Problem of Maintenance.**—This still leaves us with a last postulate: that of maintenance of correction, granted that such correction were possible, and that forced flexion were the only avenue through which it could be accomplished. And it is in this point of maintenance of correction that the redressive conservative methods have failed.

4. Modern Operative Methods

The problem of maintenance of correction was revived with the introduction of operative methods. Since then the outlook as to the permanency of the corrective results have become more favorable.

a. **Operations on Ribs.**—If we except the report by Adams in 1910 on the removal of the 5th lumbar transverse process in a case of secondary scoliosis, and others of similar nature, there were up to this time, only sporadic reports in the literature of operative procedures. These consisted in the main in the contributions of Hoffa,[63] Hoessli,[59] and Lange,[85] which concerned themselves mostly with operations upon the ribs. To this may be added the contribution of Hoke,[64] in this country, to the question of the rib resection in structural scoliosis. Sauerbruch,[124] drawing upon his large experience in lung surgery, points out to the dependency of the spine upon the position and configuration of the ribs. This is demonstrated by the changes which occur in the thorax when rib resections are performed for tuberculosis; and still more marked were the changes found after paravertebral resections of the ribs in scoliotic spines. The thorax becomes considerably narrowed in the operative side, while on the other side it becomes enlarged, so that when operaton is performed on the concave side, in certain cases, overcorrection results. On the basis of these principles a number of rib resections on the concave side were performed and reported by Hoessli[59] and by Sauerbruch[124] (1919). But even this radical procedure did not actually change the deformity of the scoliotic spine but merely increased the compensatory cervicodorsal curve. Double rib resection was then carried out by Sauerbruch, who thereby obtained a degree of correction not obtainable otherwise. All in all, the resection of ribs as a means of correcting rigid scoliosis did not offer any great hope for either correction or improvement (Lange[84]). An operative method on the muscles of the back, devised by Schepelmann, is of more academic interest. Believing that the longitudinal muscles of the back, that is, longissimus dorsi, and iliocostalis, are overactive on the concave side, while the transverse muscles, trapezius, latissimus dorsi, and serratus anterior, are in control on the convex side, he changes the insertion of these muscles. The longitudinal muscles are shifted over the spinous processes to the convex side of the curve, while the transverse musculature is freed from its insertion in midline and displayed laterally more to the concave side. No definite results have been, as yet, reported.

b. Operations upon the Spinal Column.—A more general interest in the operative treatment of scoliosis followed the work of Albee and Hibbs on the methods of fusion of the spinal column. The precise and highly developed technic and the substantial information on early and later end-results, instilled confidence in the methods and favored their acceptance. They are, however, still far from being universally recognized in the treatment of scoliosis.

Lange,[84] who claims priority for his method introduced his technic of wiring the spinous processes together, and later, used strong silk sutures and finally celluloid splints to prevent the collapse of the spine, a method originally intended for the stabilization in spinal tuberculosis.

In the technic of the operations of both Albee[4, 5] and Hibbs,[55] the aim is the formation of bony bridges between the posterior portions of the vertebrae. In the technic of Albee this is accomplished by the insertion of a tibial graft, and in the method of Hibbs by the formation of bone bridges between the neural arches, the reaming out of the intervertebral articulations and the breaking down of the spinous processes. The bony bridges which are produced form in the end a solid fusion between neural arches and spinous processes. Of the solidity of the spine obtained by either method the writer has satisfied himself repeatedly at secondary operations. After the Albee operation the tibial graft is firmly fused to the spinous processes between which it had been inserted. After the fusion operation of Hibbs, a solid plate is produced uniting the posterior portions of the spinal column (DeForrest Smith[143]). Furthermore the possibility of obtaining fusion even in young children has been demonstrated at autopsy, where the same solid fusion was observed (DeForrest Smith[143]).

(1) *The Technic of Albee's Operation for Scoliosis (Albee[191] quoted).*

''The spinous processes of the curve are laid bare by a curved incision similar to the incision used in Potts' disease. The muscles and ligaments over the tips and between the spinous processes are split into approximately equal halves with a scalpel. The spinous processes are then also split longitudinally into halves and at the same time one-half is set over to give room for the graft to be placed between. With a flexible probe or caliper the contour and length of the graft is determined. The tibia is then flexed upon the thigh and its anterointernal surface is laid bare. A flexible probe pattern is applied to this exposed tibial surface and is outlined in the periosteum with a scalpel, its length having been determined by previous measurements with the caliper. With a motor saw the graft is then cut out and removed, including the full thickness of the cortex. This graft is then placed between the already prepared halves of the split spinous processes while the patient is held in corrected position. The tissues are then drawn over the graft with interrupted suture, and the wound is closed by chromic gut and a dressing is applied. A plaster bed previously prepared is ready for the patient and he is bandaged into it. After six weeks of recumbency in this plaster bed, a well-modeled plaster cast is applied to the spine to remain for ten to twelve weeks.'' (See Chapter VI.)

(2) *The Technic of Hibbs' Operation for Scoliosis (Hibbs,[189] quoted).* (Plate LXIII, 3, 4.)

"The tips of the spinous processes are first exposed. The periosteum over the tips is split longitudinally and stripped to each side with a periosteal elevator, whereby the plane in which the stripping is to proceed is indicated. The entire dissection of the posterior aspect of the spinal column must be carried out subperiosteally. The interspinous ligaments are further stripped back and gauze packs inserted to prevent oozing. Proceeding from one vertebra to the other, always keeping strictly in the subperiosteal plane, dissection is then carried out farther and farther upon each vertebra until gradually the spinous processes are completely laid bare. Then the posterior surfaces of the laminae begin to appear and finally the bases of the transverse processes. The dissection must be carried out systematically and painstakingly. As the neural arches are becoming exposed, the ligamenta flava attached to the margins of the laminae and the articulations of the lateral processes are reached. These ligaments are carefully removed and all soft tissue is painstakingly resected until the entire posterior aspect of the spinal column lies completely bare.

"The fusion proper is started by first destroying the intervertebral articulations which beforehand must be thoroughly exposed. One proceeds with the curette systematically from one vertebra to the other. Bony bridges are then made by raising them from the neural arches in form of small bone flaps adherent to their base. They are made to overlap each other so as to make contact with the lamina above and below. Then one proceeds to the breaking down of the spinous processes with a specially constructed forceps, and the broken down tips are laid over each other so as to make a continuous line. This ends the plastic work. The entire periosteal sheath which had been stripped off unbrokenly is now brought together in midline and sutured with interrupted catgut sutures." (See Chapter VI.)

Kleinberg[80] emphasizes the advantage of beef bone graft which may be prepared in advance and does not need to prolong the operation.

The writer applies additional beef bone grafts for better stabilization of the sacrolumbar junction.

Following the operation the patient is placed upon a posterior spine brace, or, as the writer prefers, in a bivalved plaster bed with the two halves strapped to each other, this bed having been prepared a few days before operation. The patient remains in this bed for a period of eight weeks, or he is given a plaster jacket after the lapse of four weeks, remaining in bed for another four weeks. During the period of recumbency the patient may be turned without danger. He is allowed to be up in his plaster cast but should not walk around freely until after the lapse of several months. He is then supplied with a back brace which gives him freedom of locomotion.

(3) *The Technic of the Operation of Forbes[43] is similar to the technic of Hibbs.*

Forbes' operation consists in a very thorough gouging out of the entire posterior aspect of the vertebrae so as to form, as he expresses, a regular forest of bone. The bone chips are left in situ and in the course of time they form a solid sheet of bone over the posterior aspect of the vertebral column similar to that obtained by Hibbs' technic. Immediately after the operation Forbes gives the patient's spine the best possible correction by traction and rotation. A plaster cast is then applied while the patient is still under the anesthetic, or, if the patient's general condition does not permit it, the plaster jacket may be applied days or weeks later.

(4) *The Method of Schede.*[132]—Believing it is possible to support the lumbar spine by means of a bone prop applied in corrected position Schede uses a graft reaching from the crest of the os ilei to the transverse process of the 1st lumbar vertebra. This is done after the best possible correction of the overhang of the body and a compensation of the curve has been obtained. This graft can be maintained alive and is strong enough to support the body weight. It also gradually increases in thickness but loses in length, so that a certain loss of the correction must be calculated. The encroachment upon mobility is very small and no subjective complaints are made.

c. The Clinical Efficiency of the Fusion Operations.—That the operative fusion of the spine in scoliosis offers a degree of stability not obtained by other methods of treatment there is no doubt. It is, without question, the best means to obtain a passive control of the spinal balance. It is founded upon the argument that, as long as muscular control sufficient to ensure body balance cannot be obtained, the best possible solution of the problem is the abolition of all motion, thus rendering the balance of the spine entirely automatic and passive. From this point of view some believe (Hibbs) that no case of scoliosis will hold unless it is fused. In general, however, there is still a good deal of hesitancy to accept, as a routine method, an operation of such magnitude and severity. In his report of 1924, Hibbs[56] states that the fusion is effective in preventing the progress of the deformity in cases in which muscular imbalance already existed. If the operation was performed before a gross deformity had developed, it was easier to prevent the deformity. After fusion the upright position is maintained with greater ease and the trunk movement is exercised with less fatigue. According to Hibbs the operation should be performed before gross deformity has developed. In the fifty-nine cases of this report the mortality was 3.5 per cent.

Whitman[154] believes that inasmuch as the prognosis as to arrest of the deformity is uncertain in a case of structural scoliosis, the only means of improving the actual deformity and the external appearance of the trunk, would be an apparatus on the principles of the corrective plaster jacket; he believes that the spine must be held corrected for a period of years while accommodating changes take place, and that the advantage of the fusion operation of scoliosis is that many years of a plaster jacket are avoided and the period of treatment is thereby considerably shortened.

According to Kleinberg[80] the results obtained by operation compare, in point of maintenance of correction, very favorably with the use of the plaster of Paris jacket, braces or gymnastic exercises. Under the Whitman technic of traction and hyperextension and subsequent fusion operation, Kleinberg finds the end-result in a large series of cases as follows: fixation of the spine and prevention of the increase of the deformity is accomplished. Flexion and extension is remarkably restricted, and, in many cases, completely eliminated by operation, but there is always some lateral motion, and it is difficult to decide whether this is entirely in the vertebra below the operative area, or due also, in some measure, to motility of the section operated upon.

In general, the fusion operations for scoliosis are not accepted without substantial restrictions. For instance, the milder cases are held exempt from the operation by many surgeons, on the grounds that these, under gymnastic treatment, show inclination to remain stationary. It may be surprising to find the operative indications drawn rather tightly, in general, when one considers the acknowledged failure of usual conservative methods in point of maintenance of correction. The fact remains that most of the students of scoliosis, and even those who have given ample thought to the operative side, still limit their indications in the belief that there is still a possibility of regaining the natural body balance by active muscle control. Even in the absence of complete anatomic symmetry a restoration of muscle balance with maintenance of position seems possible within certain limits. It is for this reason, principally, that the fusion operation in scoliosis as the last factor in the treatment has not been generally accepted without ample reservations.

5. The Treatment of Scoliosis by Compensation (Steindler[145, 146])

a. Theoretical Considerations.—The outstanding lesson learned from the study of the scoliosis treatment as it has developed in the past, is, that the structural element of the scoliotic deformity is not amenable to correction. This still leaves open the question whether or not the contractural element of the deformity can be corrected. We have seen that inclination deformity, if not already the primary type, sooner or later becomes superimposed upon a primary inclinatory or collapse deformation of the spine. But still the question remains whether forcible correction of the contractural part of the deformity is advisable or not, and if it is, to what degree it should be carried out.

For the total habitual scoliosis and especially for the scoliosis of the paralytic type which are prevailingly of contractural nature, forcible correction by one or the other of the methods described no doubt would bring about a great deal of improvement of the original curve and with it, also, a general alignment of the body. In other cases in which the inclination deformity is secondary and is superimposed upon a primary collapse deformity, forcible correction would be a very doubtful blessing. The point which must be kept in mind above all others, is, that forcible redressment not only changes the form of the curve, even though it never entirely cor-

PLATE XXVIII

Fig. 1.—Passive mobilization. Development of lower curve.

Fig. 2.—Passive development of upper curve.

Fig. 3.—Passive symmetrical exercise for development of anterior and posterior groups of musculature.

Fig. 4.—Oblique Zander seat. Development of lower curve.

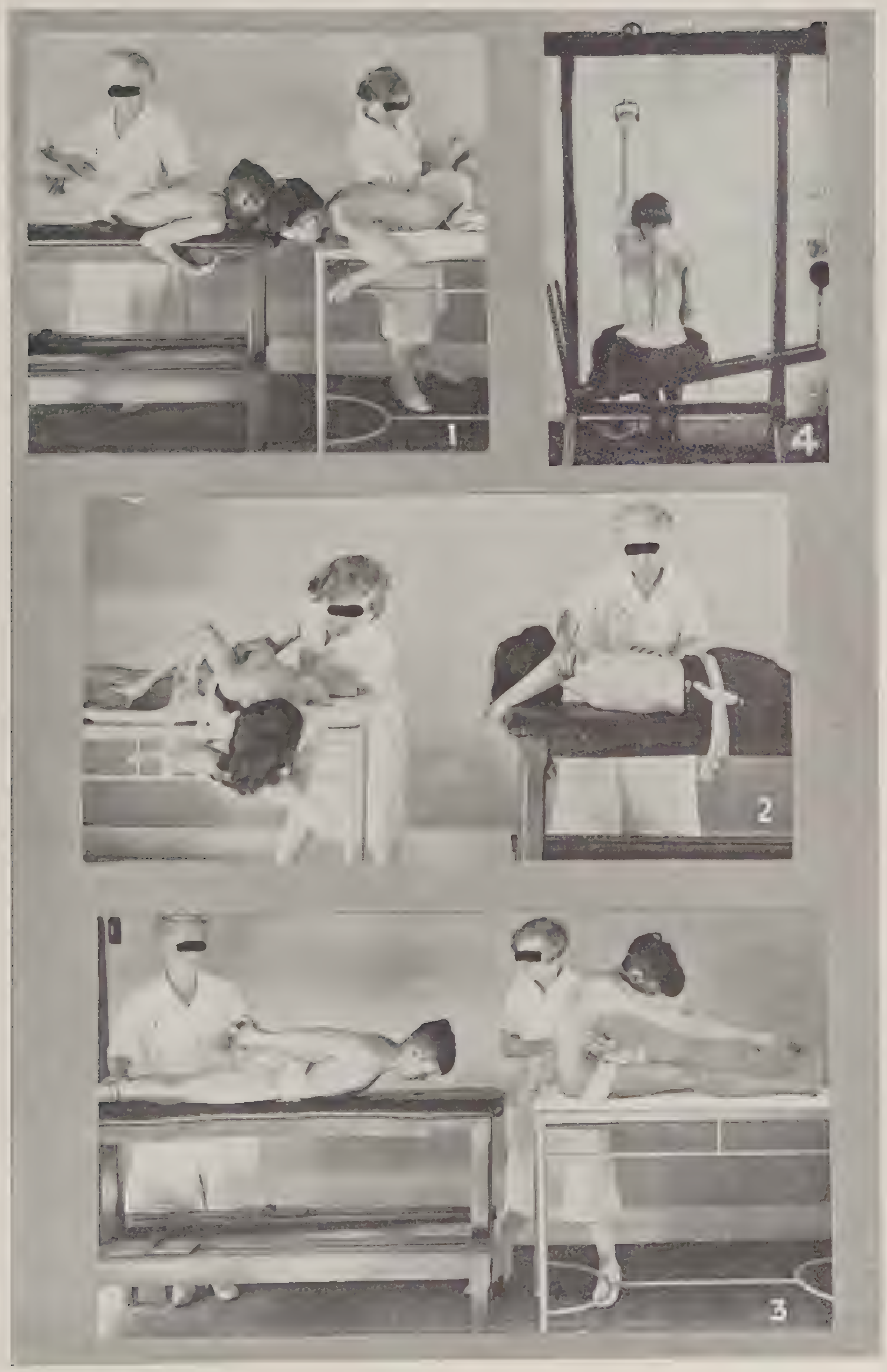


PLATE XXVIII

PLATE XXIX

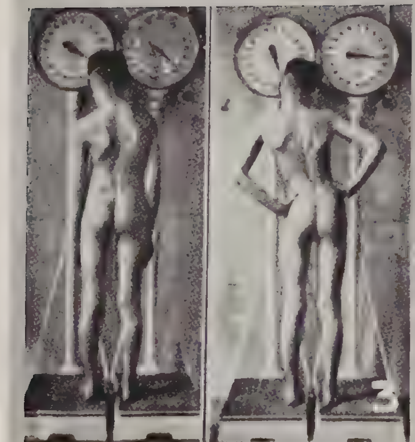
Fig. 1.—Creeping exercises (Klapp).

Fig. 2.—Body twisting exercise.

Fig. 3.—Effect of body shifting upon weight. Measured on twin scales.

Fig. 4.—Shifting exercise.

1



3

PLATE XXIX

rects it, but that in doing so, it also gravely interferes with the resistance and consistency of the curve by loosening the intervertebral and costovertebral connections as well as the ligamentous reinforcing apparatus which holds the curve in the assumed shape. It follows, then, that in most of the curves, the only practical and tangible result of forcible correction must be a greatly increased flexibility and collapsibility of the spine while the improvement over the original shape of the curve always remains limited.

Any student of modern scoliosis treatment must realize that if the usual methods have failed of their purpose, and it is generally believed that they have, it is because they were unable to secure any degree of stability after the correction had been obtained. It was from this point of view, namely, from the view of stabilizing the obtained correction that the advent of surgical procedure was welcomed as the finishing step in the treatment of scoliosis. By many it is still considered to be the only logical solution. This would seem sound reasoning assuming that all corrective measures necessarily render the spine unstable and that they increase the danger of collapse, and that this damage can only be remedied by subsequent operation.

We must ask ourselves, however, is it necessary to adopt the corrective treatment which destroys the rigidity of the curve and increases the danger of collapsing? Is not a fundamental error being committed by sacrificing the rigidity of the original curve for the doubtful benefit of incomplete correction?

b. Natural Compensation.—It would seem that a lesson could be drawn from the behavior of the scoliotic curve in its natural course, as we study the manner in which the tendency of the scoliotic spine to collapse is met by a natural functional adaptation to the changed static conditions.

The development of counter-curves above and below the original curve is a characteristic feature in the life and development of scoliosis. It plays an important part in the natural check and control of the curve.

The carriage of the head, the movement of the shoulder girdle, of the pelvis, the gait, and other factors combine in producing counter-curves above and below the original deviation, obviously for the purpose of counteracting the detrimental mechanical effect of the primary curve upon the balance of the body as a whole.

Again, if one wishes to study the progress of the scoliotic deformity, one must begin with the prescoliotic stage. In this period recovery from postural anomalies to complete symmetry is possible by muscular effort. Later, when the attitudinal asymmetry becomes habitual, although more or less under control, the child enters the scoliotic stage. We see that muscular equilibrium is always in danger, but that it is lost not suddenly but gradually.

Later again, the curvature enters into the contractural stage, and from then on no active return to symmetry is possible. If it were possible to restore absolute anatomic symmetry, then the condition could be reduced to normal, provided that the muscle control is unimpaired or can be brought up to the physiologic standard.

But what about the partial correction which is the only one obtainable? Partial correction lessens the curve but does not restore the muscle equilibrium any more than any other deformity partially corrected and exposed to weight bearing. We know that the partially corrected clubfoot is no better than one not corrected at all, and in some respects worse, since it has lost its firmness and rigidity. Precisely the same holds true for scoliosis, when treatment has produced a relaxed, loose, and collapsible spine without restoring it to absolute symmetry. On the other hand, if the natural rigidity of the scoliotic curve has been left intact, it may become a stable factor in the scheme of the general alignment of the body.

One cannot fail to recognize and to respect nature's effort to realign the body in the presence of a rigid scoliosis. She accomplishes this by the establishment of compensatory curves. The production of these compensatory curves is favored by two important elements: the element of orthopsy or straight vision which develops his cervicodorsal counter-curve, and the mechanism of the gait, the motions of the pelvis, etc., which keeps the lumbar spine movable and free to balance the trunk squarely over the pelvis, and which develops the lumbar counter-curve. (Plate XXXII, 2a, 3a.)

c. **Natural Decompensation.**—Now, in studying cases of structural scoliosis, one notes that a number of them find a natural solution in this arrangement. They become stationary at an early stage of development and remain so. In the majority of cases, however, this early arrangement of compensation becomes inadequate. The musculature is not strong enough to maintain the body balance against the force of unevenly distributed body weight. Then the symptom of the so-called overhang or body tilt develops. To use another term, the compensation of the spine which has been maintained up to this point, now breaks and a state of decompensation follows. Such an occurrence results in a more rapid disalignment of the body as a whole. The trunk is forced to lean strongly to the side of convexity, and the pelvis moves to the opposite side, causing the opposite hip to protrude. Trunk and pelvis, therefore, undergo a sideways motion in opposite direction, the trunk moving to the side of deformity, the pelvis to the opposite. The fulcrum about which this motion occurs lies at the lumbodorsal level; but this is not the only place where the equilibrium of the spine is overthrown. The upper end of the dorsal curve is also weighted down by the head and, taking a sharp turn to the side of the concavity, thereby accentuates still more the existing dorsal curve. But because of its natural mobility the lumbodorsal junction is especially prone to yield under the weight of the body and to give rise to the overhang or tilt just described.

Looking over his series of over seven hundred cases of scoliosis, the writer finds that this decompensation occurs at this level with a frequency of 77 per cent, which is easy to understand when one considers the concentration of mobility in the lower dorsal and upper lumbar segments. We notice also in these decompensated cases that the rotatory element of the

PLATE XXX

Fixation Period

Fig. 1.—Seat for application of cast.

Fig. 2.—Compensation cast applied.

Fig. 3.—Posterior view of finished compensation cast.

Fig. 4.—Anterior view of same.

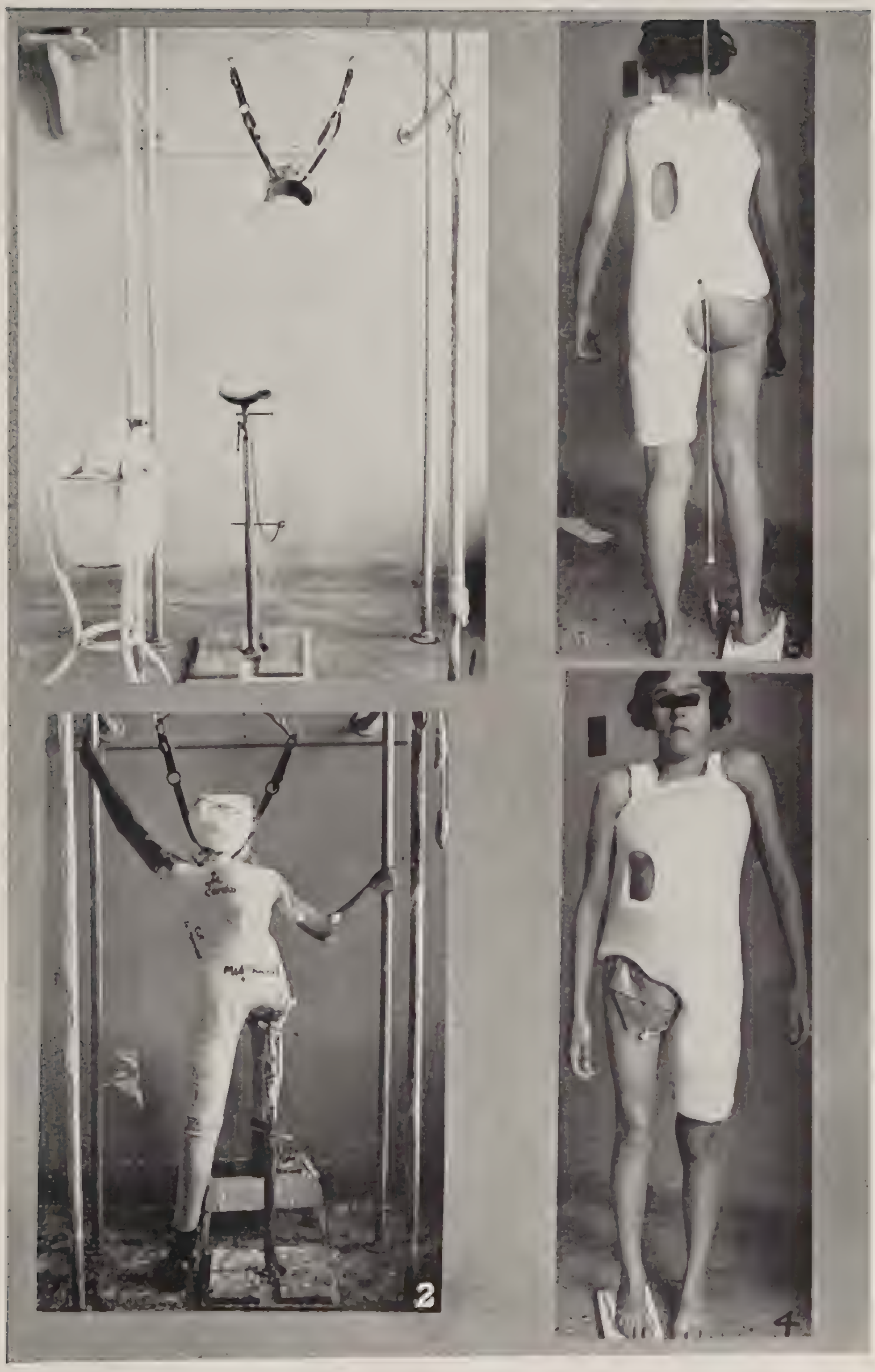


PLATE XXX

PLATE XXXI

FIXATION PERIOD

Fig. 1.—Scoliosis brace with leg extension during muscle reeducational period. Anteroposterior view.

Fig. 2.—Same, posterior view.

Fig. 3.—Same, lateral view.

Fig. 4.—Similar brace. Posterior view.

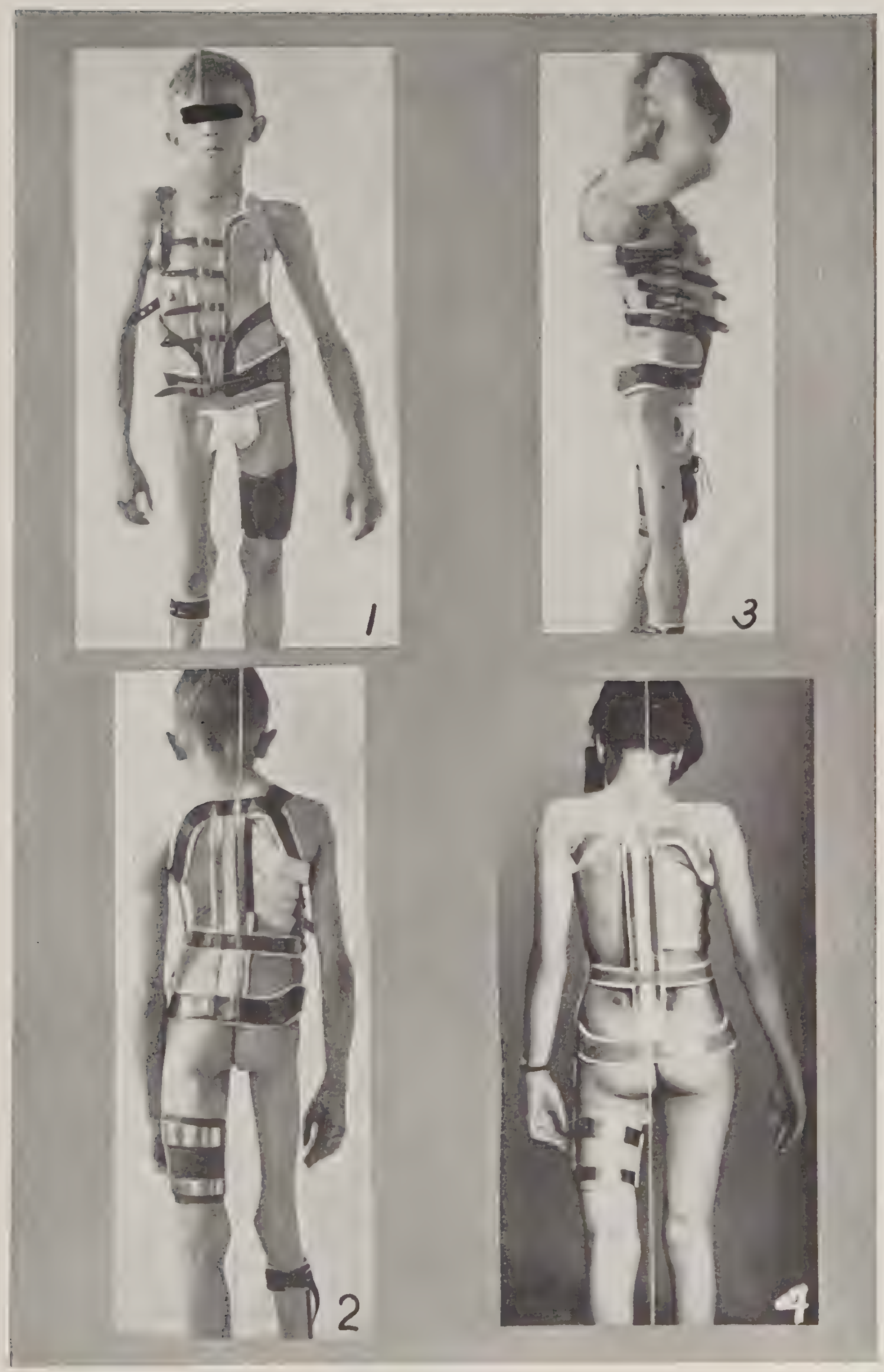


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PLATE XXXI

PLATE XXXII

Fig. 1.—Forcibly corrected in 1923 (A, B). Collapse 1925 (C, D).

Fig. 2.—Natural compensation. Note correct alignment. (Observed three years.)

Fig. 3.—Natural compensation. Curve noted since childhood. Arrested.

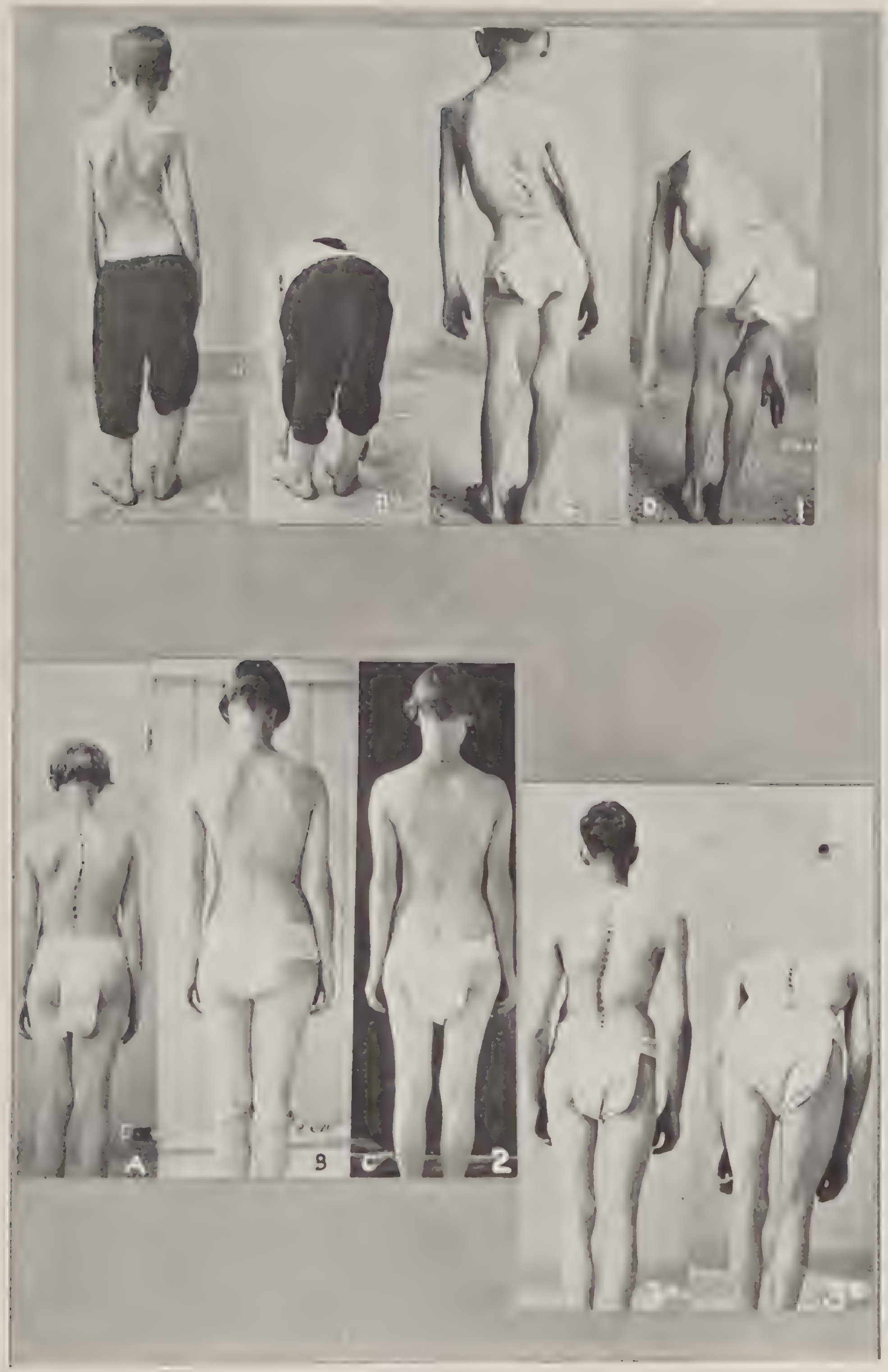


PLATE XXXII

deformity becomes more pronounced. We find the pelvis on the convex side twisted backward, and on the concave side, forward. If, however, a lumbar curve develops to compensate the primary right dorsal, then we see the position of the pelvis becomes reversed, its left half is now rotated backward and its right half rotated forward. Assuming that the left pelvic half is rotated backward, and the feet point straight forward, then, the left hip must be held in inward rotation, and, conversely, the right hip, as the right pelvis is rotated forward, must be in outward rotation. Later on this compensation may break again. When this occurs, the body again lists more strongly to the side of the dorsal convexity and the pelvis goes over to the opposite side. We see, then, that the lumbar curve is drawn gradually into the dorsal curve and becomes effaced or submerged in it. We may say that the decompensation makes the primary scoliotic curve longer at the expense of the secondary compensatory curves.

d. Principles of Compensation Treatment.—After these short preliminary remarks we may proceed with the statement of the principles embodied in the writer's treatment by compensation. This treatment simply advocates the reestablishment of compensation, which had been lost, by the development of compensatory curves of adequate degree to realign the body: shoulders square over pelvis, pelvis square over ankles.

In the general plan of this treatment the three cardinal principles of Hoffa are duly represented: the mobilization, the realignment or compensation, and finally, the retention by stabilizing the result obtained.

The treatment differs principally from corrective methods in that no relaxation of the rigid curve is intended and no force is applied for such purpose. All mobilizing is directed toward the superincumbent and underlying portions of the spine. The compensation curves are formed entirely from the movable and noncontracted sections. As they are developed they draw within their limits, more or less, the pliable ends of the primary scoliotic curve, and the latter, thereby, becomes shorter. By this recurving of the spine into an "S"-shape, the center of gravity is again placed in midline and the gravital stresses again appear more evenly distributed. In developing the upper and lower compensatory curves one must take into consideration both the lateral and the rotatory element. The lateral element is taken care of by raising the concave side shoulder and lowering the concave side pelvis. The rotatory element is provided by rotating both shoulder girdle and pelvis in a direction opposite to the rotation of the primary curve.

These short statements suffice to indicate the principles which guide the treatment of scoliosis by compensation.

e. History of Compensation Treatment.—Many conceptions of older writers on scoliosis implied a tacit recognition of the dangers of relaxation of the spine as well as of the practicability of realignment by compensation.

The first conception of active compensation was expressed by Lorenz.[87] Schede,[131] speaking of the muscular, attitudinal anomalies in the beginning scoliosis, gives a wide berth to the possibilities of active self-correction, though in structural scoliosis he still clings to the principle of passive correction of the deformity. Yet he recognizes the inefficacy and inadequacy of horizontal or diagonal forces applied to the scoliotic portion of the spine, and realizes the danger of collapse after relaxation of the spine by traction. He is fully aware of the importance of shifting the surplus body weight to the side of the concavity, thereby giving a certain recognition to the active compensatory methods of treatment.

The method of maintaining body equilibrium by active self-correcting shifting exercises is used by a great number of orthopedists. It is based upon the principle of reversal of gravital stresses from the convex to the concave side, accomplished by muscular effort, that is, by active self-correction. If the surgeons include in their treatment extension and relaxation methods, they obviously must put sufficient trust in the musculature to maintain active equilibrium in spite of the relaxed condition of the spine. The compensation principle also appears, intentionally or not, in the newer treatments inaugurated by Lovett.[168] In his previous methods of treatment Lovett had been making lateral pressure upon the prominent part of the thorax and applying the jacket under this pressure. Lovett's turn-buckle jacket is an adjustable arrangement so constructed that by the use of turn buckles the upper and lower halves of the jacket can separate on the concave side, while hinged together on the convex side opposite the boss of the curve. But there is no mechanical effect imparted to the original curve; the mechanical effect is spent entirely on the recurving of the upper and lower sections of the spine, and a compensation effect of realignment is the result.

f. The Author's Technic of Treatment by Compensation.—The treatment is divided into three periods or phases: (1) gymnastic treatment or mobilization of the nonrigid portions of the spine; (2) a period of maintenance of the compensatory curves by plaster fixation or braces; and (3) a period of stabilization of the body alignment.

(1) *The Mobilizing Period.*—

a. Scoliosis Gymnastics.—Scoliosis gymnastics consist of passive mobilizing methods: body swinging, manipulation of the pelvis, etc., in order to secure the best possible mobility of the lumbar spine. All kinds of mechanical devices, including the oblique Zander seat, are used for this purpose (Plate XXVIII, 1, 2, 3).

b. Active Mobilizing Exercises.—One of the most useful is the creeping exercise of Klapp with its great mobilizing effect upon the lumbar spine (Plate XXIX, 1).

Another is the body shifting which carries the dorsal curve as a whole to the opposite side, to or past the plumb line, and thereby increases the lumbar secondary curve, and redistributes properly the center of gravity.

It can be shown that by shifting the body weight to the concave side the surplus body weight, which originally appears convexly, becomes now greatly

PLATE XXXIII

COMPENSATION TREATMENT

Fig. 1.—Rachitic scoliosis. Curve noted at age of five years. (A) Eight months prior to Compensation Treatment. (B) (C) (D) Compensated. Holding for past twenty-seven months. (E) Home gymnasium.

Fig. 2.—Paralytic scoliosis. Compensation treatment. Paralysis involving both lowers eight months prior. (A, B). Now holding (C, D). Three years since compensation.

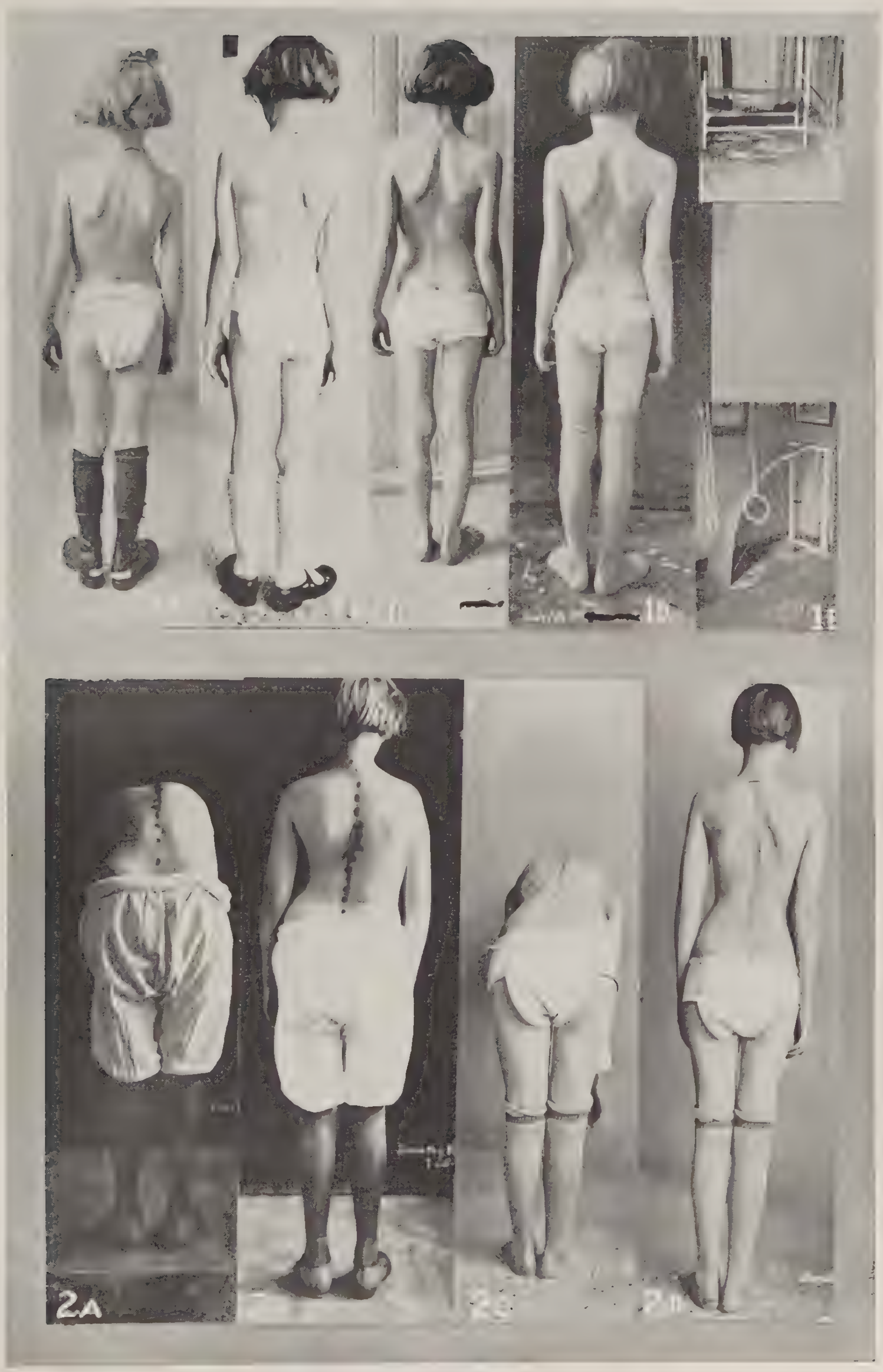


PLATE XXXIII

PLATE XXXIV

Compensation Treatment

Fig. 1.—Habitual scoliosis. Compensation treatment. Holding eighteen months to present date.

Fig. 2.—Habitual scoliosis. Compensation treatment. Curve progressed for two years previously in spite of brace support. Compensation developed (B) and holding since.

Fig. 3.—Habitual scoliosis. Compensation treatment. Holding.

Fig. 4.—(A) Combined rachitic scoliosis.
(B) Natural compensation breaks.
(C) Compensation treatment followed by fusion. Holding.

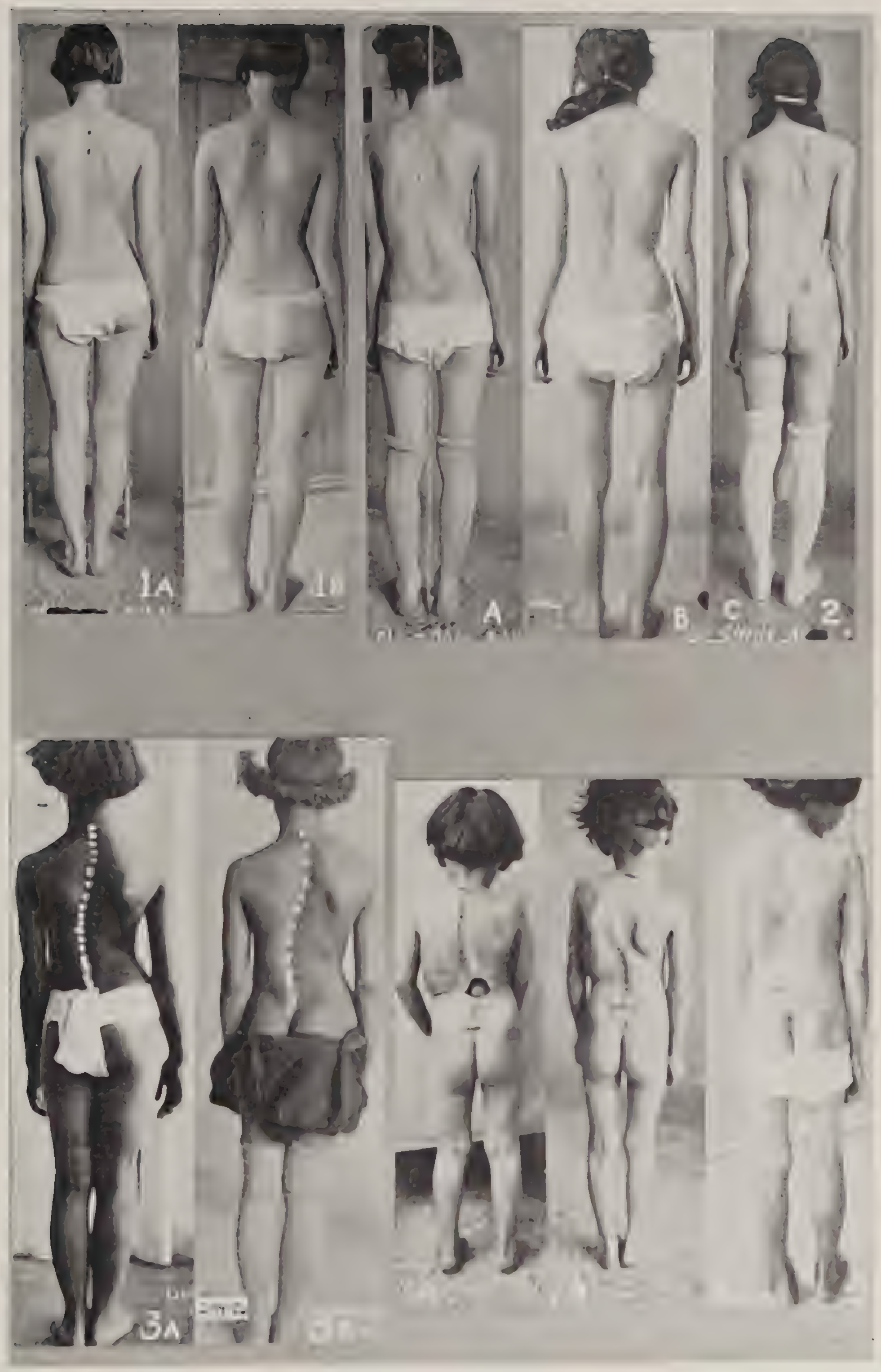


PLATE XXXIV

preponderant on the side of the concavity. The ability of self-correction by shifting must be checked up on the scales. It appears from weighings upon twin scales that while in condition of decompensation the posterior half of the body carries the overweight, self-correction by side shifting causes excess of body weight at the anterior half. So the center of gravity which originally had been displaced convexly and backward, moves now concavely and forward, that is, in a diagonal direction (Plate XXIX, 3, 4).

To these exercises of self-correction a number of useful setting up exercises may be added, such as those devised by Estor[37] and Roederer. Here, belong the asymmetrical forward thrust or sally exercises. They are accompanied by proper movement of the shoulder girdle, and are admirably fitted to procure the necessary mobility of the upper portion of the spine.

The time required for complete mobilization of both the lumbar and cervicodorsal sections and for the full development of compensatory curves by gymnastic exercises varies greatly. In some cases two or three weeks are sufficient, and in others several months of intensive gymnastic training become necessary. These exercises are combined with general exercises of symmetrical nature, and especially with intensive training and development of the muscles of body and back. Massage, Swedish gymnastics, wand, dumb-bell, and club exercises are given at the same time.

(2) *The Fixation Period.*—The compensation acquired during the period of gymnastics is then stabilized by the application of an adequate plaster cast. These jackets are applied in upright position with the head in a Glisson swing, but no traction is applied except as much as is necessary to hold the head stable. Assuming that the primary curve be a right dorsal, the patient stands with his left leg in abduction of about 20 degrees, or better, he is riding upon a specially constructed seat under his right buttock, letting the left half of the pelvis drop and the left leg, thereby, go into abduction (Plate XXX, 1, 2). The left arm is raised high and the right arm is lowered and the patient is told to shift into a position of self-correction. Muslin straps or the hands of the assistant placed diagonally at the posterior and anterior costal prominence steady the trunk. This position brings out the compensatory curve to the best advantage. Compensatory rotation of the upper and lower sections of the spine is simply carried out by either stabilizing the rigid midportion of the spine and rotating the left half of the pelvis and the left half of the shoulder girdle backward, or else the midportion may be rotated against both shoulder girdles and pelvis, the latter, at the same time, being held fast. The mechanical effect is the same whether one tries to rotate shoulder girdle and pelvis against the primary curve, or the primary curve against shoulder and pelvis; the principal point is merely that rotation of shoulder and pelvis are opposite to that of the rigid scoliotic curve. We notice that the position of the pelvis now is completely reversed from that it occupied before; then, the right pelvis was rotated backward and now, it is the left; then the right hip was in inward rotation, and now, it is the left; then the right side of the pelvis was lowered and now, again, it is the left. We have, then, a complete rever-

sal of the condition existing before, so far as the upper dorsal and lumbar spine is concerned. A cast is then applied in this position. From the mechanical situation it is obvious that the abduction position of the left leg and the dropping of the left pelvis must be maintained; therefore, it is absolutely essential that the left thigh be included in the cast in the case of right primary dorsal curve and vice versa. In this case, then, all requirements of compensation are satisfied: the body is shifted back to the concave side, the pelvis to the other, and shoulders and pelvis are again truly aligned over the ankles. Changes of the casts are made at intervals of two to four weeks until it appears that compensatory curves are sufficiently and permanently established. The cast period may be set variously from one or two, to five months and more, according to the degree of compensation which is to be maintained (Plate XXX, 3, 4).

(3) *Stabilization.*—When the cast is definitely removed the question of further proceedings is to be decided upon the point that either maintenance of the body balance can now be trusted to the musculature, or else the case is to be assigned to operative fusion. We have already stated that a number of orthopedists believe that all cases ought to be fused because none of them are able to maintain their balance by their own muscular effort. We believe, however, that there are a great many cases well enough endowed with musculature, cases that are past the period of rapid growth and cases where the compensation obtained is complete enough, in which one may reasonably hope that the balance of the spine may be maintained by active muscle force. That a spine well compensated by the development of a triple scoliosis, well aligned, will maintain its balance under favorable conditions is a matter of almost daily experience. We see numerous spines come to a more or less spontaneous arrest of development. We have followed for years a number of cases which have regained their balance by way of compensation and have maintained it. Such cases, after the removal of the cast, must necessarily undergo again a rigid muscle training for a period of years; they must be fully instructed in their daily exercises and must be impressed with the fact that the continuance of these for a long period of time is an absolute necessity. They are given a retentive brace pending the period of muscle development. This brace is essentially of the same shape as the plaster cast or shift cast; it has an extension which includes the thigh on the side opposite the primary dorsal curve. This brace is worn for a period of a year or two, or as long as it is necessary to accomplish the reeducation of the musculature of the back (Plate XXXI, 1, 2, 3, 4).

In a large number of cases, however, possibly in a majority, it will be a question whether the equilibrium can be maintained by active muscle control or not. If the cases have an actual muscle loss, as in all paralytic conditions, or if the deformity has become so advanced and rigid and decompensated that the development of compensatory curve is impossible or entirely inadequate, as in most congenital and many rachitic curves, then the operative fixation can hardly be avoided unless the patient prefers to wear an external support

PLATE XXXV

Fig. 1.—Habitual scoliosis.

- (A) On admission. Incomplete natural compensation. Right overhang.
- (B) Compensation treatment.
- (C, D) Fused and holding. Was fusion necessary?

Fig. 2.—Habitual scoliosis.

- (A) On admission. Decompensated.
- (B) Partially compensated. Right overhang.
- (C) Partially compensated and fused. Right overhang.
- (D) Breaking. Compensation probably not complete.

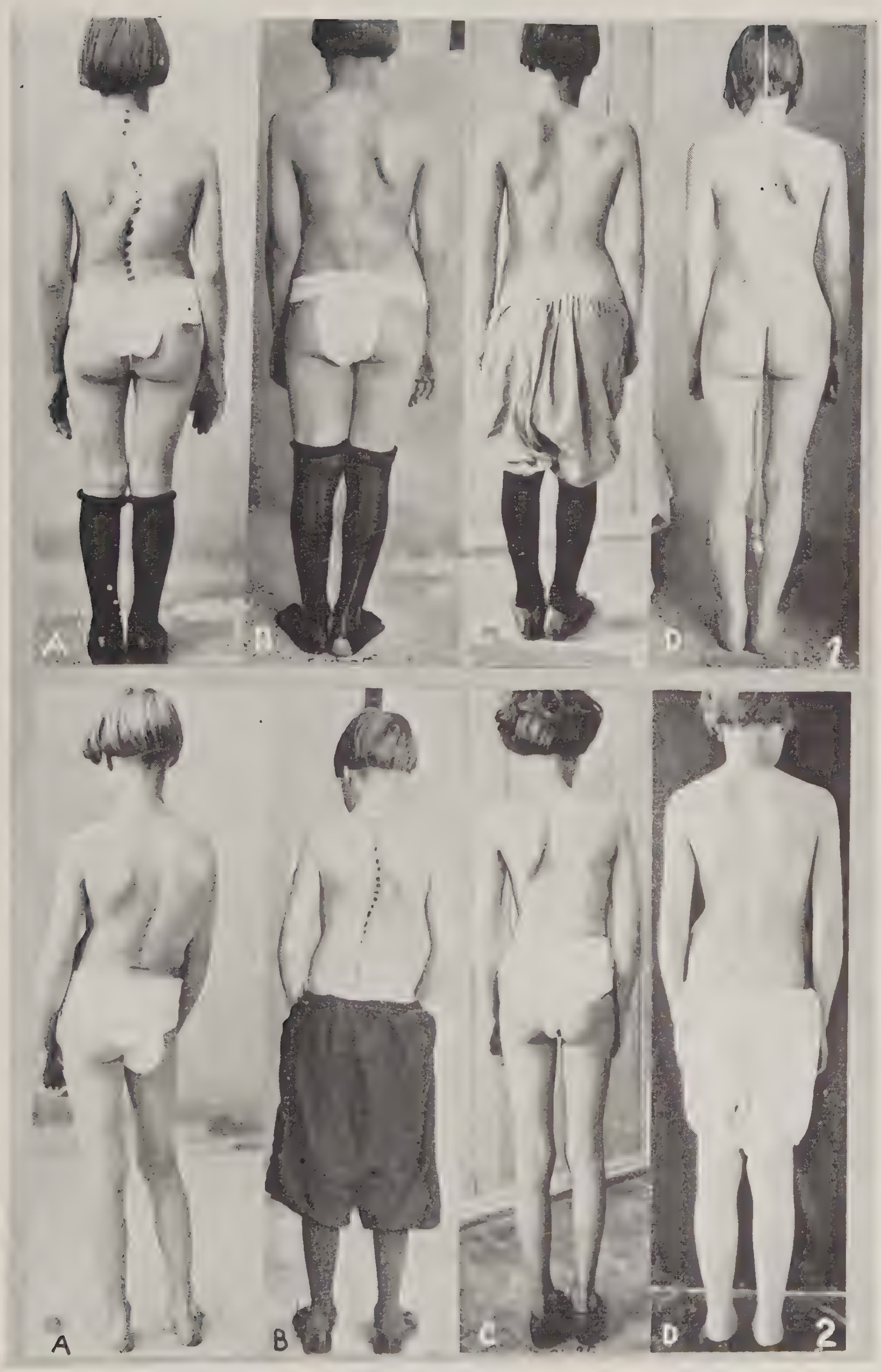


PLATE XXXV

PLATE XXXVI

Fig. 1.—Paralytic scoliosis.
- (A) Decompensated.
- (B) Compensation treatment begun.
- (C) Partially compensated.
- (D) Partially compensated and fused. Total compensation not obtainable. Apparently holding since.

Fig. 2.—Habitual scoliosis.
- (A) Decompensated.
- (B) Compensation treatment.
- (C) Compensated.
- (D) Fused in compensation and holding.

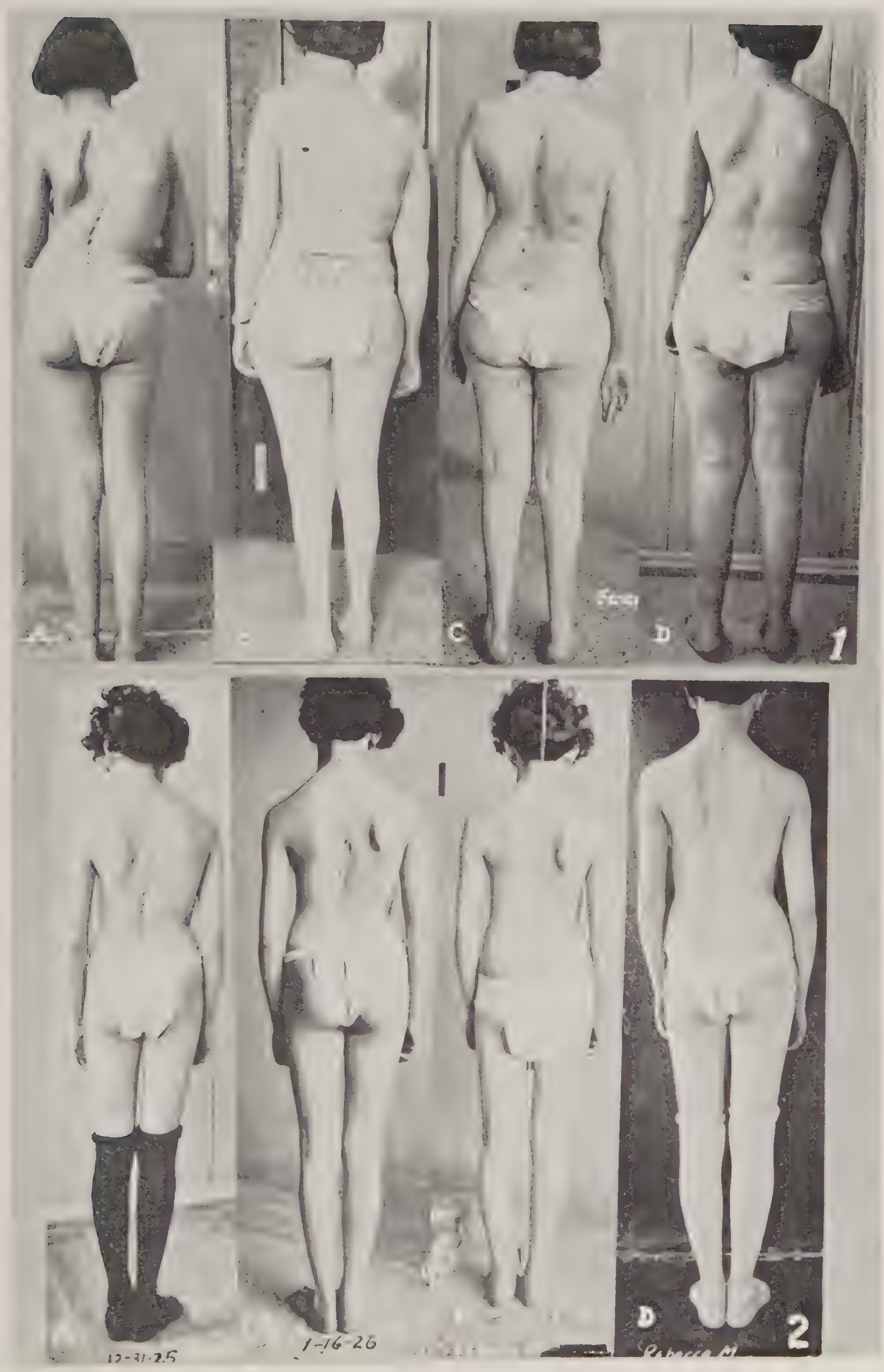


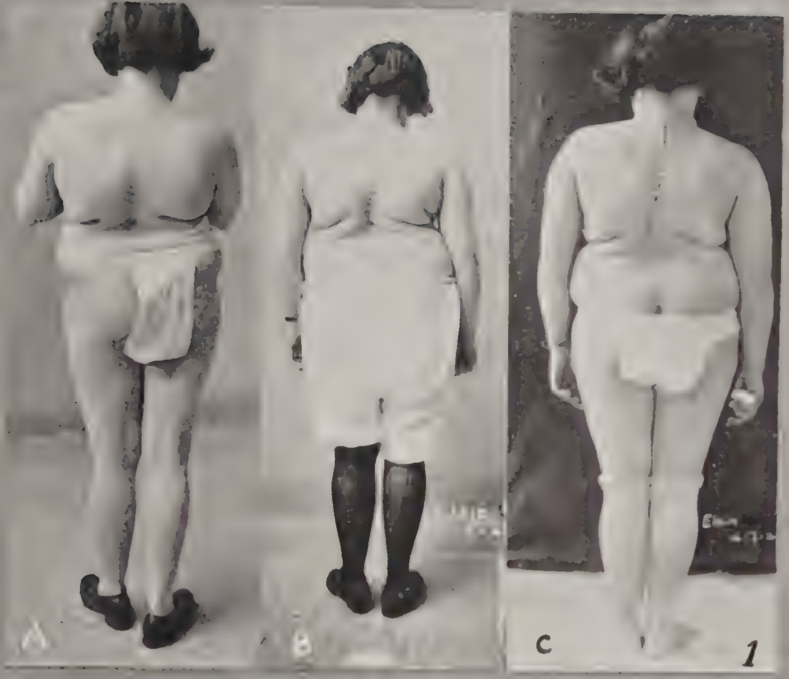
PLATE XXXVI

PLATE XXXVII

Incomplete Compensation and Fusion

Fig. 1.—Rachitic kyphoscoliosis. (A)
(B) Partially compensated.
(C) and fused.
Holding. Reason: probably because of safeguarding effect of anteroposterior curve.

Fig. 2.—Severe scoliosis.
(A) Decompensated.
(B, C) Compensation only partial.
(D) Partially compensated, fused and holding in brace. Fusion indispensable.



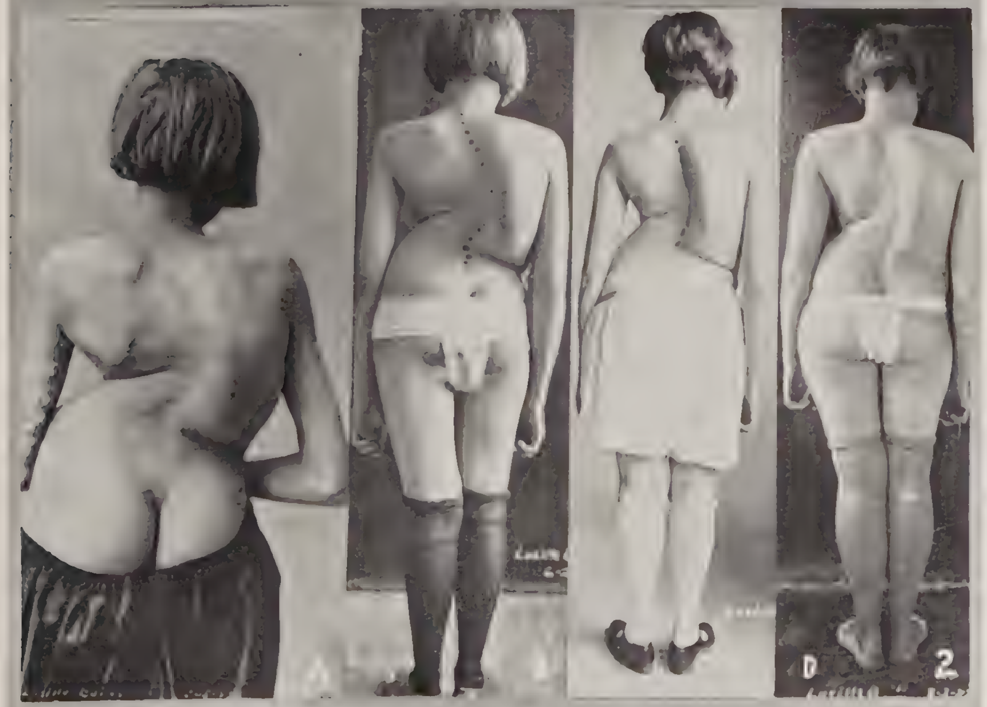


PLATE XXXVII

PLATE XXXVIII

Compensation Not Obtainable

Fig. 1.—Rachitic scoliosis.

- (A) On admission.
- (B) Compensation treatment started.
- (C) Compensation not obtainable.
- (D) Realignment of body not possible. Arrest doubtful even if fused.

Fig. 2.—Paralytic scoliosis. (Paralysis in 1917.)

- (A) On admission.
- (B) Compensation started.
- (C) Very incomplete compensation and fusion.
- (D) Beginning break.
- (E) Pronounced break after eighteen months. Reason for break: impossibility of obtaining alignment.

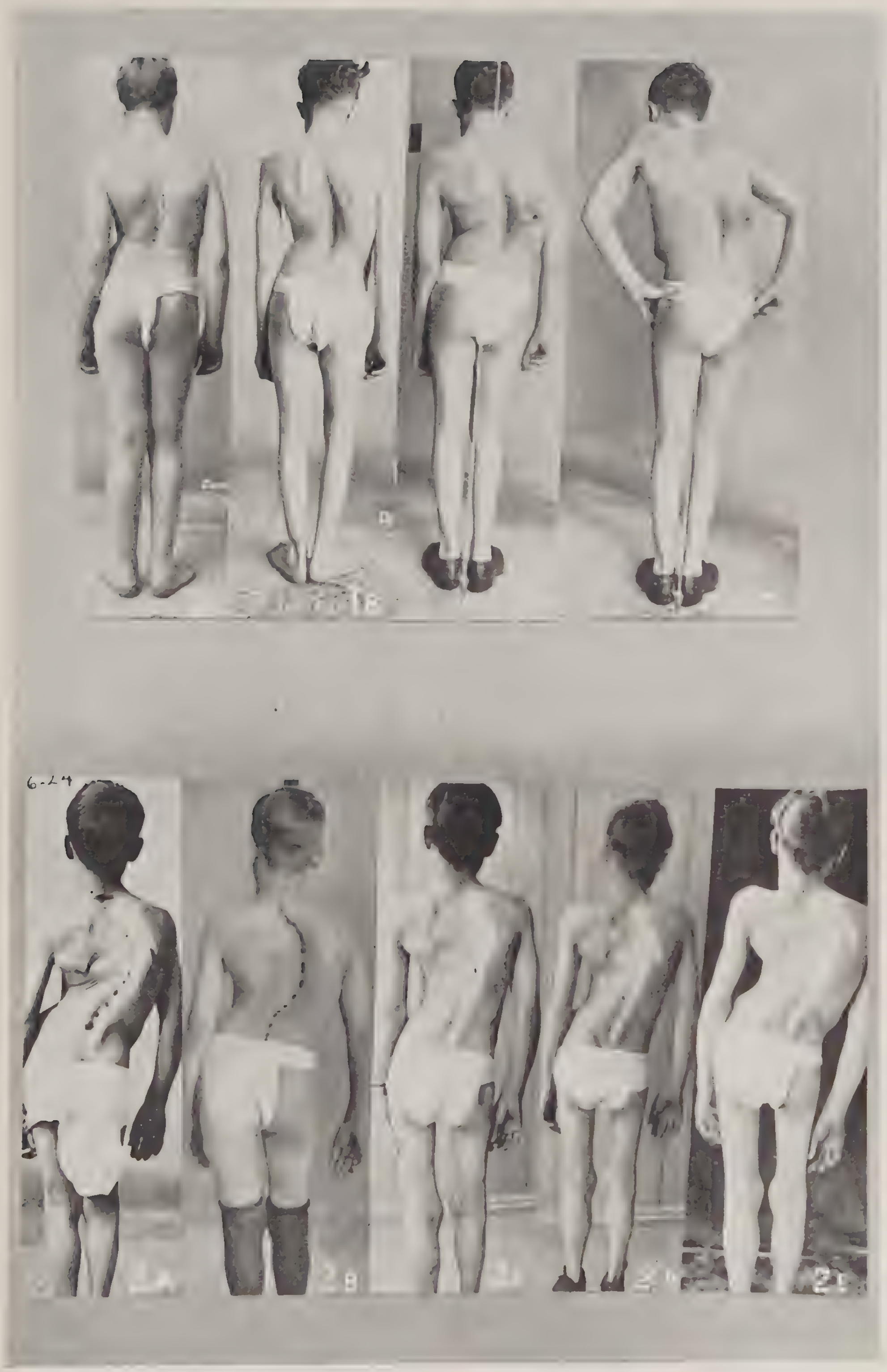


PLATE XXXVIII

for an indefinite period of time. The operative fusion procures, indeed, a very elaborate stiffening of the curve, especially in the dorsal section. In a series of over one hundred fusion operations for lateral curvature of the spine, performed by the writer, there was no operative death, although as many as fifteen vertebrae were fused at one time. On the other hand, the so-called break or false motion in a fused spine is very frequent. Almost regularly this false motion is found in the lumbar spine, especially in the lumbodorsal section. That this is not a matter of technic has been proved to the writer by frequent reoperations, at which the neural arches appeared as solid plates of bone for long distances, and only one distinct point of false motion existed. The cause of this must lie in the exceptional mobility of the region and in the exceptional strain to which it is subjected. The number of cases in which false motion was established at this point exceeds 50 per cent, and some of them had to be operated upon again to maintain balance. Many others, however, thanks to the better developed muscles of the body, were able to hold the body in balance in spite of the pseudarthrosis at the lumbodorsal section. It appeared quite plainly, however, that the grossly decompensated spines were much harder to hold even after the fusion than those that had previously been reduced to a state of compensation. Practically all cases which showed "breaks" or pseudarthroses of the dorsolumbar region were cases not compensated or only incompletely compensated, although pseudarthrosis was not entirely confined to the incompensated cases. There is, therefore, a place for compensation treatment even in those cases, which, from the beginning, are designated for operative fusion.

In the light of the experiences made with all methods of scoliosis treatment one is justified in saying that operative fusion while at this time accepted as a temporary solution, does not entirely solve the problem. In the advanced deformities of noncompensated cases it will be the only refuge, and we owe a debt of gratitude to those who have developed the method and perfected its technic. As a definite solution, however, the situation as it stands now is not entirely acceptable. The solution rather lies in early recognition of the prescoliotic state and adequate prophylactic measures. In the management of the already developed deformity one must keep in mind nature's way of coping with the situation. In doing so, one is led unfailingly to refrain from the meddlesome relaxation methods and to respect the natural rigidity of the curve as a valuable asset in the scheme of body balance. It is hoped that when this attitude is carried through consistently a number of cases now relegated to operative fusion can be brought to more natural physiologic and permanent outcome by compensation methods and by development of a muscular apparatus adequate for the permanent maintenance of body balance (Table II, Chapter III; Plates XXXII to XXXVIII: Results of compensation treatment with and without fusion. See Legends).

TABLE II

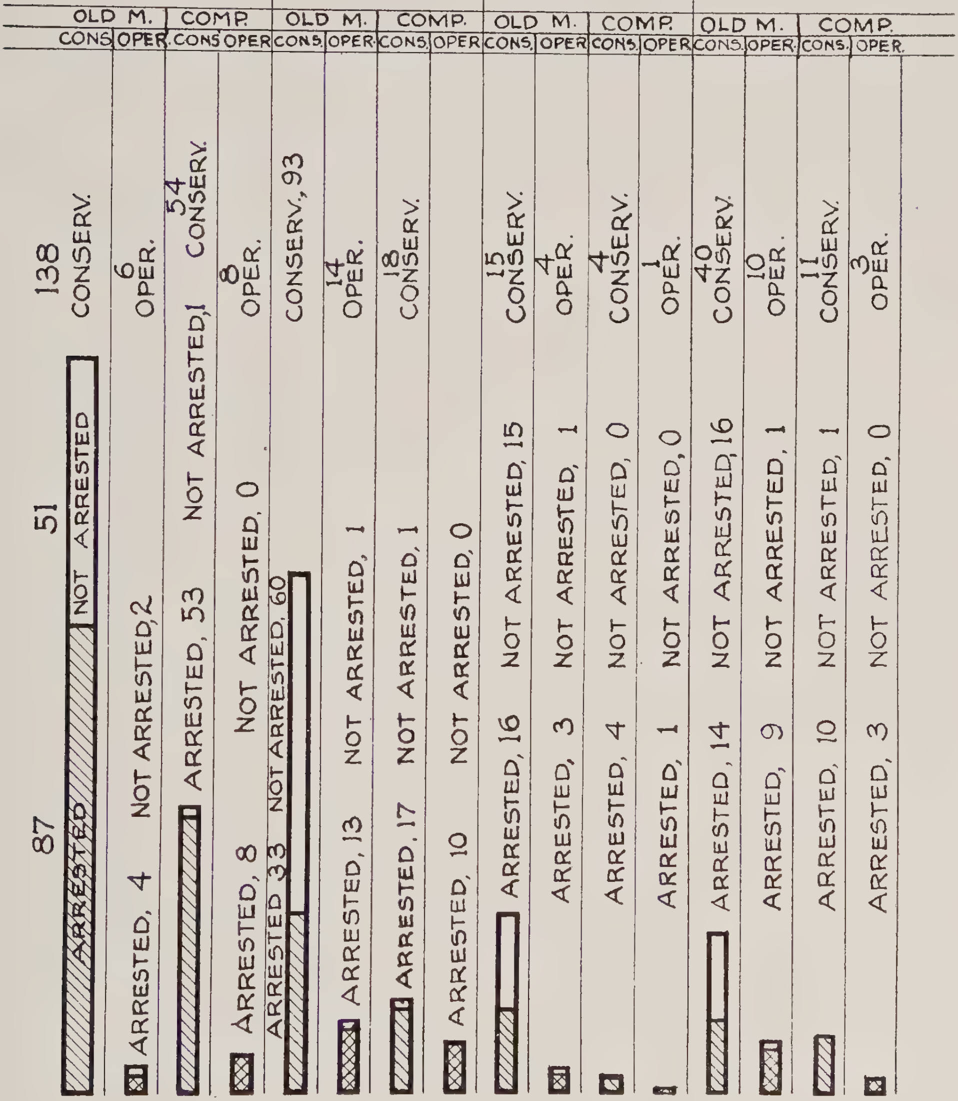
Scoliosis Chpt. III. Statistics of Treatment.

I. Habitual S. 335
TREATED 208
DORSAL 82
LUMBAR 46
COMBINED 144
LEFT TOTAL 63

II. PARALYTIC SC. 216
TREATED, 135
DORSAL 79
LUMBAR 27
COMBINED 70
TOTAL 40

III. RACHITIC SC. 63
TREATED 40
CERVICAL 1
DORSAL 20
LUMBAR 18
COMBINED 20
TOTAL 4

IV. CONGENITAL SC. 90
TREATED 64
HIGH DORSAL 21
DORSO LUMBAR 43
COMBINED 24
LUMBO SACRAL 2



XII. COMMENT ON CHAPTER III: SCOLIOSIS

In this chapter the attempt is made to show that with all their vicissitudes, the views and conceptions regarding scoliosis represent a coherent story. We have seen how the ideas on scoliosis mechanics have been inaugurated by Meyer, and how they were brought to great precision and given an admirable working application by the later investigations of Lovett. Great clinicians like Bouvier, Schulthess, and many others have molded the clinical pathology of the condition into strong relief, so that it is now possible to give as concise a pathologic picture of scoliosis as of any other orthopedic condition. More recent years have witnessed great contributions in the field of pathogenesis, and even more recently the possibilities of prophylaxis have been brought to attention.

There has been, and there still is, a great deal of dissatisfaction over the manner in which the treatment of scoliosis has developed. This is perhaps justified, but it should be remembered that in this respect also the situation has become considerably cleared by the development and recognition of the three principles of mobilization, correction, and maintenance, so ably formulated by Hoffa. It is strange how laboriously and slowly this triad of principles which constitutes the sane foundation of scoliosis treatment has asserted itself in the minds of orthopedic surgeons. Not so very far back the field was held by extremists; one of the prerequisites of treatment was favored at the expense of the others. We have mentioned methods which emphasize mobilization, others that emphasize immobilization, as the keystone of treatment. Surely, both views cannot rightly apply to the same condition. It is peculiar also to note how long the problems of forcible correction have dominated the field. Only recently the orthopedic mind has become conscious of the fact that the maintenance of the correction is the all-important point. It does not matter so much by what means the three basic conditions of the treatment, namely, mobilization, correction or compensation, and stabilization or maintenance are satisfied. The great advance in scoliosis treatment has been that each of these is being accorded its rightful place. One may summarize the therapeutic aims of modern scoliosis treatment as follows: one mobilizes in order to align or correct; one corrects, by plaster or otherwise, in order to maintain the correction. As long as the mobilization and correction are subservient to the maintenance of balance as the ultimate postulate, and not opposed to it, they are not only justified but are a necessary and integral part of the treatment. In other words, the treatment of scoliosis is not only a problem of orthopedic surgery, but also of orthopedic reconstruction; it is a problem in which all natural resources of the body must be engaged. But natural resources in their development take their own time and are not to be hurried or coaxed.

Having demonstrated that both mobilization and correction, or compensation, of the deformity, are merely steps leading to the problem of maintenance, it is further attempted to show that maintenance in scoliosis is not a problem that is best solved by totally abolishing the mobility of the spine, in other words, by operative fusion; although, in many, if not the majority of cases, one has to accept this compromise. In many other cases, however, we have shown that the return to normal balance by way of mobilization and compensation and ultimate redevelopment of muscle forces of the back, is possible; and, furthermore, that such is the most natural and the more desirable solution of the problem. But such a solution is, again, a laborious piece of reconstruction which takes years of work and many more years of supervision.

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CHAPTER IV

FRACTURE AND DISLOCATION DEFORMITIES

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  - 3. Double Rotatory

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    1. Mechanism
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XI. Comment on Chapter IV: Fractures and Dislocation Deformities

The discussion of recent fractures and dislocations, not being within the scope of this treatise, is restricted to such pertinent points as are necessary for the understanding of the resulting deformities and disabilities. Mechanogenesis and syndromes of acute traumatic conditions will be viewed from the same angle. According to Kocher[47] a practical division may be made between partial and total lesion. To the partial lesions belong the isolated dislocations of the articular processes, the isolated fractures of arches and processes of the vertebrae; to the total lesions, the lateral fracture dislocations of the dorsal and lumbar spine, the anteroposterior fracture dislocations of the cervical spine, and the fractures of the vertebral bodies.

I. ISOLATED DISLOCATIONS OF THE ARTICULAR PROCESSES: UNILATERAL AND BILATERAL

1. Unilateral Dislocations

Unilateral dislocations are encountered most often in the cervical spine. The dislocation is caused by direct trauma, such as a blow on the neck or head which forces the head in abduction and flexion, or indirectly by a fall upon the head, or by a violent jerk. The resulting deformity is rotation to the opposite side, abduction to opposite side, and forward flexion. The neck appears longer and convex on the side of dislocation, the head is fixed by muscular contraction, and tenderness appears at the lateral process. Pressure upon the head is painful.

The reposition maneuver consists in traction in the line of deviation, abduction to the sound side, to disengage the articular process and then rotation to the dislocated side, and extension.

The dislocation becomes irreducible in about one week.

The residual deformity in unreduced unilateral dislocation of the cervical spine is rotation to the opposite side, abduction to the opposite side and flexion.

2. Bilateral Dislocation (double forward; Plate XXXIX, 1, 2)

Bilateral dislocation of the intervertebral articulations is a much rarer occurrence. It is caused by forced flexion occasioned by a blow on the neck or to the head, and indirectly, by fall. The symptoms are violent pain, rigid forward flexion, tenderness of the articular process and prominence of the lower vertebral spines. The cord is frequently involved. Reduction is carried out by forcible traction in flexion until the articulations are disengaged, then by gradual backward extension under backward pressure upon the articular processes. This dislocation becomes irreducible in a few days. The residual deformity is straight forward flexion of the head and neck with considerable restriction of motion, especially in side bending, and very often with neuralgic symptoms from impingement of cervical roots.

3. Double Rotatory Dislocation

In double rotatory dislocation of the cervical spine below the second cervical the head is held forward and rotated to the side of the posteriorly dislocated articulation. It is abducted with convexity toward the anteriorly dislocated articulation.

The reduction maneuver is straight forward flexion, abduction, and rotation in the direction of the deformity to disengage the articulations; then extension, and abduction-rotation to the opposite side. The condition becomes irreducible in a few days.

II. FRACTURE DISLOCATIONS

1. In the Cervical Region

a. The Atlantoaxoid Fracture Dislocation.—Very few fracture dislocations of the atlantoaxoid joint end in recovery. The mechanogenesis is usually fall upon occiput resulting in forward dislocation of atlas on occiput, or fracture dislocation of atlas. Fall upon forehead usually causes backward dislocation of the atlas (Wuesthoff[90]). The position of the head is rigid forward flexion. A depression can be felt between the spine of axis and atlas, showing that the latter has become displaced forward. The anterior tubercle of the body of the atlas (anterior ring) can be felt protruding into the posterior pharyngeal wall. Intense pain is felt in the nape of the neck and occiput, usually in the

PLATE XXXIX

Fig. 1.—Double forward dislocation of 6th cervical associated with fracture of spinous process and lamina. No cord symptoms. Permanent forward flexion deformity.

Fig. 2.—Detail of X-ray of Fig. 1.

Fig. 3.—Fracture dislocation of odontoid process. No cord symptoms.

Fig. 4.—Fracture dislocation 2nd and 3rd cervical vertebrae showing forward flexion deformity.

Fig. 5.—Showing foreshortening of cervical spine.

Fig. 6.—Side view showing fracture dislocation. No cord symptoms.

Fig. 7.—Frequency Table (from Wallace) of fracture of vertebral bodies.

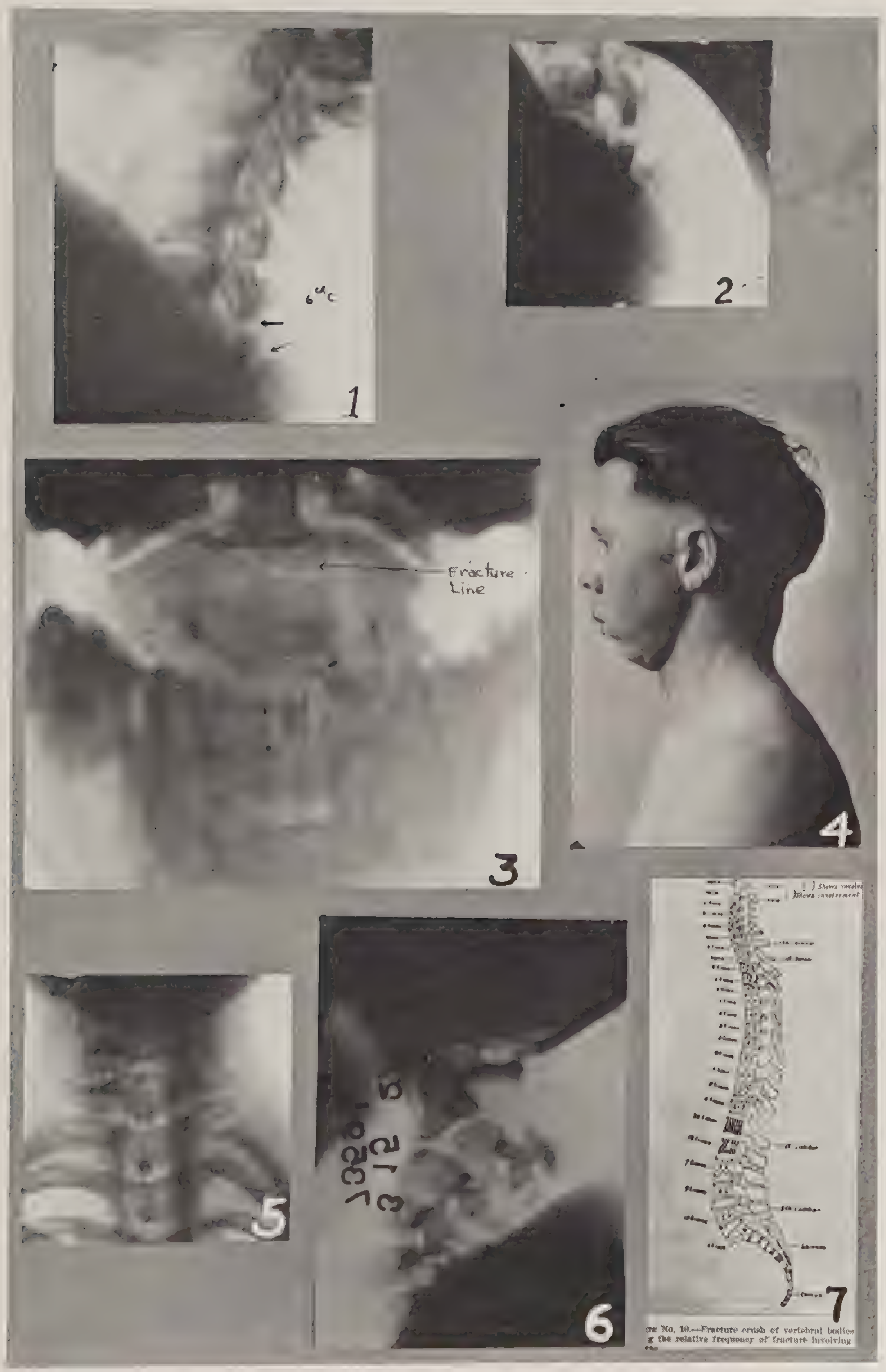

1
6th C
2
Fracture Line
3
4
5
6
7
Shows involvement
No. 10.—Fracture crush of vertebral bodies
the relative frequency of fracture involving

PLATE XXXIX

distribution of the occipitalis major nerve. Crepitation of the fractured surfaces of the odontoid process can be felt on movement. Difficulties in swallowing, disturbance of speech, bleeding from the nose are observed, due to injury to the posterior pharyngeal wall.

Reduction under anesthesia is dangerous and only justified in cases with severe cord lesions. The fracture dislocation very soon becomes irreducible. Residual deformity is usually ankylosis of the dislocated vertebra and rigid forward flexion of the head (Plate XXXIX, 3, 4, 5, 6). The rule that the cord is gravely involved in total dislocation of the cervical spine has its exceptions (Wagner and Stolper[84]). Two cases are reported by Blasius in 1869 with complete dislocation of the 2nd vertebra of the cervical spine without any cord symptoms, and Steinmann[78] collected nineteen cases in the literature of total bilateral dislocation of the cervical spine without permanent cord lesion. Other instances of absence of cord lesion are reported by Schranz[72] (fracture dislocation of 1st and 2nd cervical, avulsion of odontoid process); Le Breton[50] (fracture dislocation of atlas, fracture of odontoid process); Pirble[63] (fracture dislocation of the 2nd cervical in a child eighteen months old; after five months perfect control of head; no symptoms).

b. Fracture Dislocation of the Lower Cervical Spine.—Usually a forced flexion fracture due to a fall on the head, rarely by direct blow. The residual deformity is rigidity or ankylosis in forward flexion. Involvement of the spinal cord is the rule. Here, also, many cases are reported which escaped cord lesion (Hartshorn:[28] comminuted fracture of 2nd and 3rd cervical and anterior dislocation of 1st, 2nd, and 3rd without paralysis; residual deformity; stiffness of neck. Anderson:[3] extreme dislocation of 4th upon 5th cervical without cord lesion).

2. Fracture Dislocations of the Dorsal Spine

Fracture dislocations of the dorsal spine are extremely rare because of the great protection afforded to the spine by the thorax.

3. Fracture Dislocation of the Lumbar Spine

Fracture dislocation of the lumbar spine is also rare. Wagner and Stolper[84] in their collection of cases (1898), maintain that the majority of the cases reported were really fractures with very marked displacement of the fragments. Pieri[62] cites several observations of vertebral dislocations reported up to 1898. A case mentioned by Guyot and Mauclair[25] is the following: a boy of seventeen showing a dislocation located between the second and third lumbar vertebrae, had complete flaccid paralysis of the right lower extremity with hyperesthesia. The left lower showed a diminution of the muscle strength in extension while the sensibility was intact, and so were also the plantar and cremaster reflexes. The x-ray revealed a complete dislocation between the 2nd and 3rd lumbar vertebrae with lateral displacement of the 2nd lumbar to the right, this vertebra having lost completely its contact with the upper portion of the underlying 3rd lumbar vertebra. In this case the reduction of the dislocation was carried out by strong longitudinal traction, followed, after a few minutes, by lateral traction both above and below the level of the dislocation. The reduction was successful, the patient showed return of mobility and was able to walk after a period of four months. A case of total dislocation of the 2nd lumbar over the 3rd, producing complete paralysis, is reported by Costantini and Duboucher.[9] Operative reduction of the dislocation, which left the articular processes intact, but fractured the transverse processes, was successful, though the paralysis persisted. In another instance of complete fracture dislocation between the 3rd and 4th lumbar, cited by Förster,[19] with complete paralysis of one leg, reduction was accomplished by strong traction and pressure. This dislocation recurred and was again reduced. A case of almost total dislocation fracture observed by the writer showed some caudal symptoms on the side opposite to the dislocation (Plate XL, 1).

The fracture dislocations of the lumbar spine are caused by direct or indirect violence. Such direct violence with the force acting upon the spine in a transverse plane, occurs in form of a blow or kick, or the crushing effect of a wheel, etc. Indirect violence is active, for instance, in a fall upon the head.

Fractures of the neural arches may be associated with these dislocations. In the cervical region the articular processes may escape injury, but in the lumbar region a displacement is almost impossible without fracture of the articular processes.

Fracture dislocations are frequently located at the dorsolumbar junction They show a line of separation through the intervertebral discs, and, in addition to this, the anterior surfaces of the bodies of the vertebrae are often chipped off obliquely. The vertebra above the lesion carries with it the whole spine which is displaced forward as well as downward upon the vertebra below. When the spine straightens out after the blow the deformity may disappear and the vertebra springs back into the normal position. In the cervical region where the double forward dislocation may take place without fracture of the articular processes this does not occur and the dislocation remains permanent. Occasionally the vertebral body escapes injury completely so that the line of separation passes cleanly through the disc. This occurrence is most frequently observed in the cervical spine, while in the thoracolumbar region there is usually a chipping off of the vertebral bodies.

III. FRACTURE OF THE VERTEBRAL BODIES. COMPRESSION FRACTURES

1. Mechanogenesis

Compression fractures occur by direct or indirect violence, for instance, by forced flexion of the trunk against the pelvis. If hyperflexion continues further, the inelastic posterior arches may also fracture before a rupture of the elastic interspinous ligaments occurs (Osgood[59]). Sprain fractures of the

4th and 5th lumbar vertebrae have also been observed from violent contractures of the extensor muscles of the back (Radmans[66]). The fractures are situated most frequently in the lumbodorsal and the upper lumbar region. Functional disturbances are greater as a rule in dislocations than they are in fractures (DeQuervain[64]). In fracture the conditions for callus formation and consolidation of the damaged spine is favorable and even severe fractures of the spine are seen to heal with comparatively good function, provided there is no great damage to the cord. In dislocations, however, the conditions for consolidation are much more unfavorable. There is more or less interposition of soft tissue which maintains the spine in a state of instability.

2. Fractures in Cervical Spine

Fractures of the vertebral bodies are reported at every level. In the cervical spine, those associated with dislocation of the atlas have been mentioned among the fracture dislocations of the spine. The associated fracture lesion is rarely recognized because of the almost inevitably fatal outcome of such an injury (Corner[8]). Pure compression fractures of the cervical bodies by hyperflexion, without dislocation are reported in the literature. Harbitz[27] observed three cases of fracture of the 5th and 6th cervical bodies as well as of the arches, caused by violent forward flexion of the head, and a similar fracture of the 7th and 8th cervical. These cases do not show the severe and fatal cord lesions with anything like the frequency seen in fracture dislocations. Many of the cases have a free interval of days or weeks after which death may result either from injudicious movement carried out by patient or physician, or from myelitis caused by irritation or callus formation (Wilson and Cochrane[88]). Ellermann[15] reports such a case of fracture of the odontoid process in which sudden death occurred after seven weeks following a brisk movement of the head.

3. Lower Dorsal and Upper Lumbar Spine

The compression fractures of the lower dorsal and upper lumbar region are of especial interest to the orthopedic surgeon because of their frequency (Plates XXXIX, 7; XL, 2, 3, 4, 5, 6; XLI, 1, 2, 3, 4, 5, 6). It is common experience that fractures of the vertebral bodies at this level often are so free from symptoms that they become submerged in the signs of contusion of the soft structures of the back incident to the trauma (Sturgis[80]).

a. **Clinical Symptoms.**—The clinical symptoms may be divided into subjective and objective ones. The subjective symptoms are:

1. *Pain* which is constantly and persistently localized in the back. It varies in intensity; sometimes it is so mild that it will be overlooked for a considerable time or is submerged in the general symptoms of contusion; in other cases it is so severe that the patient is confined to bed and large doses of opiates are necessary to relieve him.

Referred pain may be complained of in head, back and abdomen, the upper or lower limbs, along the distribution of the spinal nerves in the vicinity of the injury. After injury of the lower dorsal spine there may be referred pain in the lower abdomen. Pain in the limbs occurs frequently after injury of the lumbar vertebrae.

2. *Persistent weakness* of the back occurs in all cases, and the patient is unable to do any, even the mildest type of work, and is unable to strain or stress the back. All motion of the spine aggravates pain.

The objective symptoms are:

3. *Stiffness and rigidity* of the back and limitation of motion in every direction. This is in contrast to sprains of the back where motion is usually limited in certain directions only.

4. *Deformity.*—In severe cases of compression fracture the change of contour of the spine is important. There appears a knuckle with sharp increase of the posterior curve of the spine. The gibbus formation is angular (Plate XL, 6).

5. *Involvement of the Cord.*—In a considerable percentage of cases of spinal fractures the cord is involved. The symptoms of cord compression may range from weakness of the limbs to complete paralysis, disturbance of sensation, loss of control of sphincters of bladder and rectum.

b. X-ray Diagnosis.—The most important feature in the diagnosis is the x-ray evidence. It is easy to recognize compression fractures in definite impaction or displacement of the fragments. In a great number of cases, however, the impaction or displacement is so mild, or deformity occurs so late that it is very essential to recognize even insignificant changes in contour and relation of the vertebral bodies. For this reason a short description of the normal anatomy of the vertebral body as seen in the x-ray will facilitate recognition of anomalies. According to Simon[75] the body of the vertebra shows, in the anteroposterior view, four transverse lines, which correspond to the upper anterior, the upper posterior, the lower anterior, and the lower posterior borders. The anterior and posterior lines can be differentiated in that the latter give a much sharper and shorter line than the former. The compressed portion between the body and the articular process is formed by the pedicles which give a heavier shadow than the rest of the vertebrae. In the anterior view the laminae usually show within the shadow of the body as a ribbon-like formation, varying in width in the different sections of the spine. In this view, also, the spinous processes must be plainly seen, their density depending upon the position of the plate. They appear in the dorsal as linear, vertical condensations of various lengths. The articular and transverse processes can be made out distinctly in the lateral as well as in the anteroposterior picture. It is essential to note the size and direction of the intervertebral articulations as well as their symmetry. Lateral views are of great advantage to demonstrate the contours of the bodies of the cervical spine. In the lumbar and dorsal sections they become less clear because of the distance of the bodies of the vertebrae from the plate.

PLATE XL

Fig. 1.—Almost complete dislocation of 2nd and 3rd lumbar vertebrae. This patient showed partial flaccid paralysis on one side.

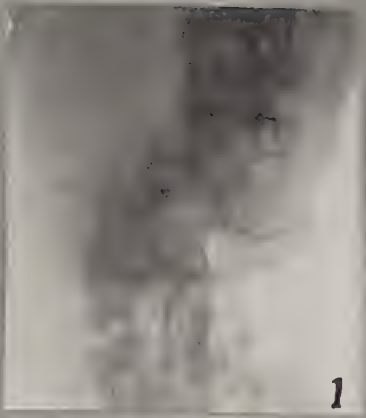
Fig. 2.—Compression fracture between 2nd and 3rd lumbar vertebrae. Crush of the articular processes.

Fig. 3.—Healed compression fracture—fusion of bodies. (Courtesy of Dr. H. J. Prentiss.)

Fig. 4.—Compression fracture of 2nd lumbar vertebra. No nervous symptoms.

Fig. 5.—Side view of Fig. 4. Note lack of healing.

Fig. 6.—Patient with compression fracture of 2nd lumbar vertebra. Note deformity. Healed and symptomless.



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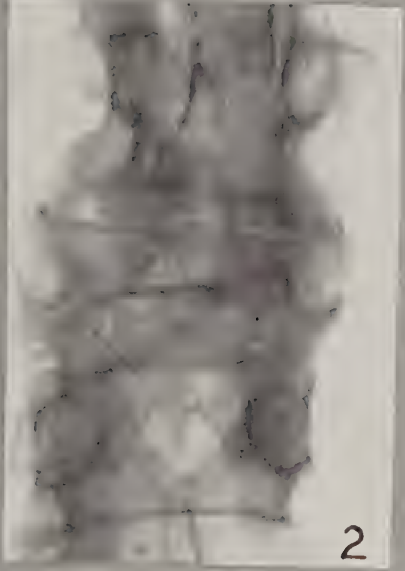

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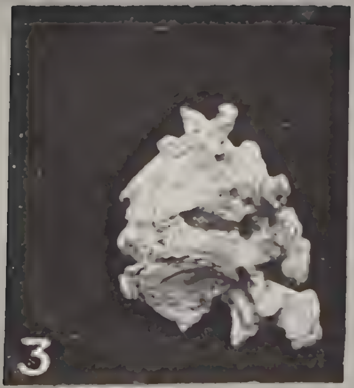

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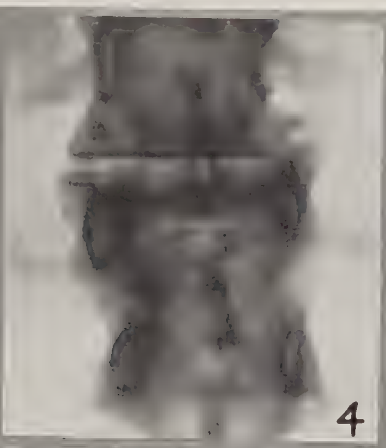

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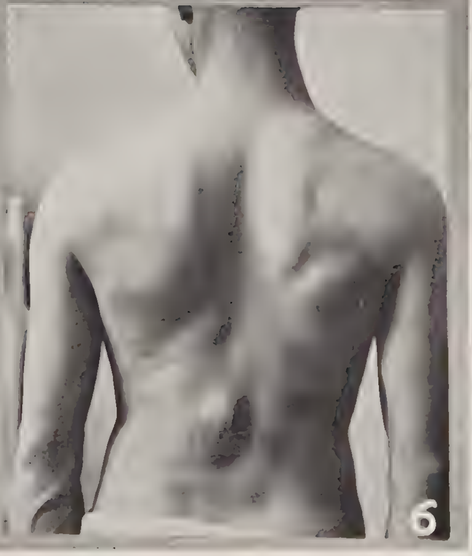

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PLATE XL.

PLATE XLI

Fig. 1.—Crush fracture of 8th dorsal in anteroposterior view.

Fig. 2.—Crush fracture of 8th dorsal in lateral view. Same patient as in Fig. 1. No cord symptoms.

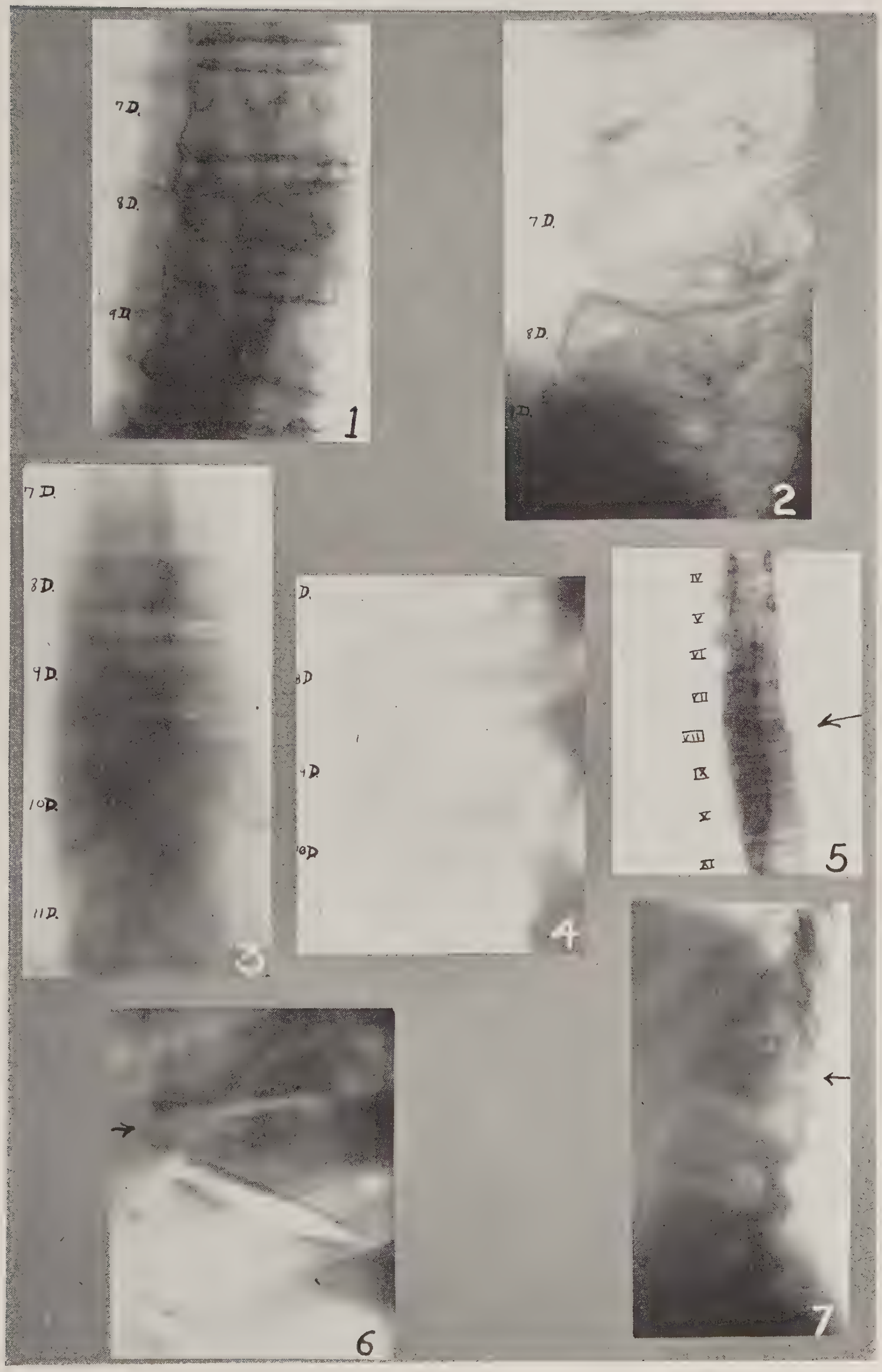
Fig. 3.—Crush fracture of 8th, 9th, and 10th dorsal vertebrae.

Fig. 4.—Lateral view of Fig. 3. Note wedge shape and elongation. No cord symptoms.

Fig. 5.—Crush fracture of 8th dorsal. Note lateral infraction.

Fig. 6.—Lateral view of Fig. 5.

Fig. 7.—Kuemmell's posttraumatic kyphosis.


7 D.
8 D.
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1
7 D.
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D.
2
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4
IV
V
VI
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XI
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PLATE XLI

For the demonstration of fractures and especially fine fracture lines and fissure fractures the lateral views are indispensable. These fractures present themselves as irregular hair line defects which reach the contour of the body where often a slight displacement may be noted. Another important point made out in the lateral view is the lessened height of the body as well as of the intervertebral discs. Hasty conclusions must not be drawn, however, because insignificant differences in height are also seen in normal pictures. It is especially desirable to demonstrate in the x-ray picture any angulation or kink of the spine. A definite lateral deviation between the axes of the adjacent vertebral bodies denotes severe injury. Small detached particles of the bodies give a diffused cloudy shadow, though at times they may be more sharply defined. The architecture of the injured vertebra also must be studied. Often it shows radical changes. One difficulty arises when the picture is taken some time after the injury. Then a good deal of atrophy and secondary changes may present themselves, and it may become difficult to differentiate between traumatic and tuberculous spondylitis. Gross bony defects in the substance of the vertebral bodies, however, are more characteristic for tuberculosis.

4. Prognosis of Compression Fractures of the Vertebral Bodies

The prognosis as to life is not determined by the fracture but by associated injuries, especially by the lesions of the cord (Kleinberg[44]). Motor paralysis, sensory disturbances of the limbs, paralysis of bladder and rectum resulting from injury or compression of the spinal cord are either the direct result of the displacement of the fragments of the vertebrae, or of edema or hemorrhage in the spinal canal. If these symptoms are due to actual destruction of nerve tissue of the spinal cord they are permanent; if due to elastic pressure, edema, or hemorrhage, they may disappear if the pressure is relieved.

In the average case of fracture of the spine with no nerve symptoms, the prognosis for ultimate recovery is good. The patient is soon able to walk, although this may be only with difficulty and caution. Some symptoms, however, may persist for a considerable length of time, especially pain and rigidity. The healing of a fractured vertebra is a slow procedure since the callus thrown out by the affected vertebrae, as a rule, is comparatively small and forms very insidiously (Plate XLI, 7). Reckoning from the time of injury, the period of disability is from one to two years. In most cases a certain impairment and weakness of the back, however, remains permanent so that the patient cannot resume any labor which requires a great deal of strain or stress.

IV. FRACTURE OF THE COCCYX (PLATE XLII, 1)

Minor displacements of the coccyx occur seldom after middle life due to the fact that the sacrococcygeal joint becomes fused at this time (Cyriax[10]). Fractures occur at the junction usually by direct violence (landing on buttocks, kick, etc.). The displacement is usually forward. Characteristic sign are the distinct pressure tenderness found on rectal examination, the forward deflection of the coccyx, and the abnormal mobility at the junction. The diagnosis is obscured by the fact that other injuries, especially sacrolumbar and sacroiliac sprains caused by the original injury complicate the clinical picture. The patients are often highly neurotic and it is important to analyze carefully the clinical syndrome so as to apportion the proper significance to the sacrococcygeal lesion. A good diagnostic point is the following: when the patient rises from the sitting position, especially when sitting in a low chair, then the contraction of the lower fibers of the gluteus maximus causes a forward deviation of the loosened coccyx and produces pain. Also the tension upon the levator ani is painful as the patient strains at stool and the pelvic diaphragm is forced downward. When one has made sure that the loosened coccyx is the cause of the trouble, the proper procedure is its removal. It can be reached easily from a curved incision over the junction and can be dissected out and removed. The finger of an assistant is introduced into the rectum and guards the posterior rectal wall against injury during the resection. A purse string suture draws the wound together.

The operative results are almost uniformly satisfactory.

V. FRACTURE OF THE PROCESSES

1. Fracture of the Lumbar Transverse Process (Plate XLII, 2)

a. Frequency.—According to the compilations of Niedlich[56] there were reported up to 1924 only 103 cases of isolated fractures of the transverse processes of the spine. Of these 103 cases reported 95 were men, 5 women, and 3 children.

The 1st transverse process was fractured 38 times; the 2nd, 34 times; the 3rd, 56 times; the 4th, 51 times, and the 5th, 23 times.

b. Etiology.—The trauma is usually directed to the lower part of the back. Following this, pain is felt which increases on motion and disappears only upon rest, so that the patient is forced to desist from work. Fractures due to direct violence, such as a blow, fall, etc., are not rare (Kennedy[41]). Less frequent are fractures due to indirect violence (muscle pull).

From anatomic considerations it can be seen that the comparatively narrow, strongly projecting transverse processes are especially exposed to muscle pull in caudal direction. This pull is the strongest at the 1st and the least at the 5th lumbar process. It is produced principally by contracture of the psoas muscle which flexes the thigh against the pelvis, and by the quadratus lumborum which pulls the 12th rib downward in lateral flexion of the spine. Of these muscles, it is the quadratus lumborum which, according to G. G. Davis,[11, 12] is of the greater mechanical importance in fractures of the lumbar transverse processes. It arises by aponeurotic fibers from the ilio-lumbar ligament and the adjacent portions of the iliac crest, and is inserted in the

PLATE XLII

Fig. 1.—Fracture of coccyx. Note fracture line and deviation.

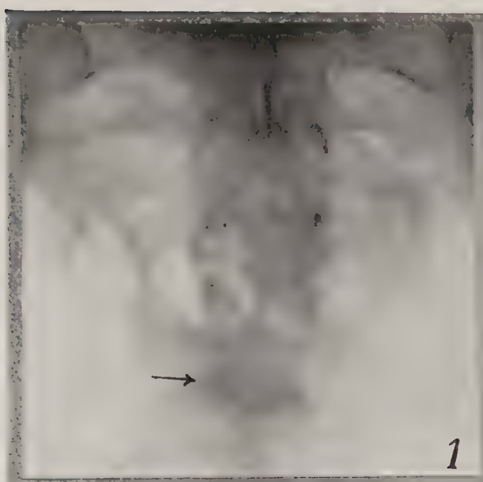
Fig. 2.—Fracture of 2nd, 3rd, 4th, and 5th lumbar transverse processes. Note displacements of fragments by muscle pull.

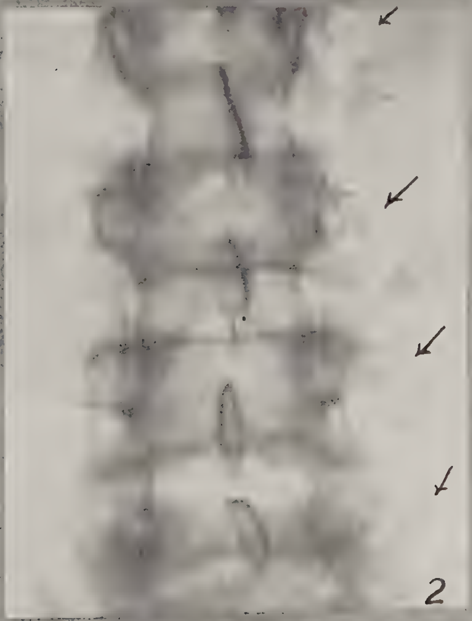
Fig. 3.—Crush fracture of left articular processes between 3rd and 4th lumbar vertebrae.

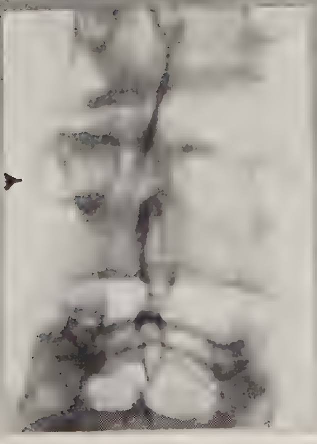
Fig. 4.—Photo of patient in Fig. 3. Note deviation of spine.

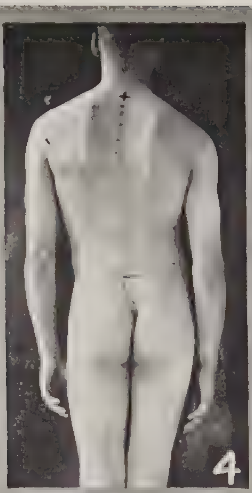
Fig. 5.—Crush fracture of right intraarticular process between 2nd and 3rd lumbar vertebrae. Note deviation of spine.

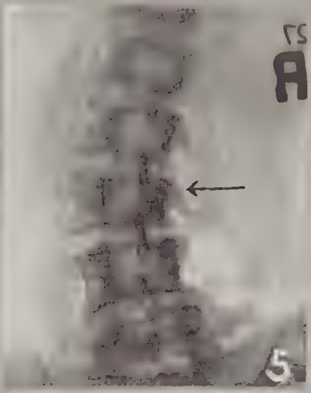
Fig. 6.—Healed crush fracture of bodies. Note callus.











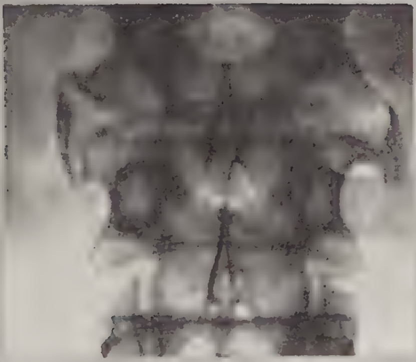


PLATE XLII

lower border of the last rib. It also sends small tendons to the apices of the transverse processes of the lumbar vertebrae. With the thorax, spine, and pelvis fixed, the force applied by this muscle may cause a fracture of the transverse process.

In a case reported by B. H. Moore[54a] the injury occurred suddenly while the patient was doing light work at the grinding machine, and there was no unusual strain or trauma. In this case an operation showed considerable necrosis of the bodies of the 3rd and 4th lumbar vertebrae with minute non-coalescing foci of tuberculosis. This fracture undoubtedly occurred by muscle pull, and it is the only case on record of a pathologic fracture of the transverse process produced in this manner. Usually a blow, a fall from a window or scaffold, in a few cases the lifting of a heavy load, were the responsible factors. Whether one transverse process is fractured or several of them depends upon the severity of the trauma and the area exposed to the direct blow. Only a few cases of unilateral multiple fractures of transverse processes are reported. These are probably caused by violent contraction of the iliopsoas while the leg is fixed in flexion (Sorge[77]). Baumann[3a] thinks that a single transverse process cannot be fractured by muscle contracture. In the few cases in which trauma could be excluded a rapid twisting movement produced the fracture, and here it could have been only the quadratus lumborum which, by violent contracture, caused the injury. Of greater importance is the action of the muscle after the fracture has occurred. The distal fragment pulls out at the site of fracture for a distance of one cm. and more. The 1st and 2nd transverse processes are usually pulled outward and sometimes upward, while the 3rd, 4th, and 5th are pulled outward and downward.

c. **Symptoms.**—On deep palpation one finds local pain at the site of the transverse processes. Active flexion of the hip-joint is painful, if not impossible, on the affected side. If the patient is able to stand there is a deflection of the spine toward the affected side. Lateral motion toward the sound side is painful. Paraesthesias may be found in the back and buttocks. In some cases the symptoms are very acute and the patient is confined to bed; in other cases they are slight, although grave enough to simulate a simple strain, and often the diagnosis of "lumbago" is made. The disability caused by the injury is largely due to the associated contusion and sprain of the back. The fracture itself is much less disabling.

Of greater importance are the anatomic relations between lumbar transverse processes and intercostal nerves. It appears that the posterior branch of the 12th dorsal, giving off a longer ramus, occasionally anastomoses with the lateral ramus of the 1st lumbar; while the median ramus of the 1st lumbar crosses the posterior surface of the 1st and 2nd lumbar transverse processes in reaching the musculature of the back. This may explain the frequency of segmental neuralgia observed after fracture of the transverse processes. The pain usually becomes well defined and localized after the more diffuse local signs of contusion have disappeared. It is exaggerated by motion which changes the weight line of the body when the patient rises from the recumbent to the sitting, or from the sitting to the erect position. Flexion and hyperextension of the spine, as well as lateral bending, cause pain. There is a great deal of muscle rigidity with a point of exquisite tenderness over the fractured process. Haglund[26] reports five cases of isolated fracture of the transverse process of the lumbar spine with local symptoms of pain, pressure tenderness, and restriction of lateral bending and rotation. A scoliotic posture existed which pointed with its concavity to the affected side; there was, however, relative freedom of motion in all other directions so that the scoliosis was to be considered as merely attitudinal.

d. X-ray Findings.—The x-ray findings are of great value. Stereoscopic pictures especially are desirable. One must beware of rudimentary lumbar ribs which may give the erroneous impression of a fracture of the transverse process. Goecke[21] points out the distinction between a rudimentary lumbar rib and a fractured transverse process in the x-ray picture: fractures show an irregular fracture line while the lumbar rib has a smooth line of articulation.

e. Differential Diagnosis.—Some retroperitoneal lesions may offer difficulties of diagnosis in the absence of positive x-ray findings; hematuria, injuries to the kidney, retroperitoneal hematoma, may be results of the injury. The contusion of the back may be associated with rigidity of the lateral and anterior abdominal wall in response to peritoneal irritation. As a rule, the history and clinical findings are able to determine intra- or retroperitoneal lesions.

f. The Treatment.—The treatment consists of rest in bed, local applications, and, in case an unabsorbed hematoma accompanies the fracture of the transverse process, in aspiration. The patients may be discharged for work after five or six weeks with a disability of 10 per cent lasting for three to six months. Long continued immobilization is no more necessary than in other contusions or sprains of the back.

According to Kennedy[41] the patients are able to walk after an average period of sixteen days. Disability extending over six months is out of the ordinary, and the majority of the cases should be at work in two or three months time, with practically no complaints referable to the injury. Cure occurs either by callus formation if the diastasis of the fragment is not great, or by absorption of the distal fragments.

2. Fractures of the Articular Processes (Plate XLII, 3, 4, 5)

Isolated fracture of the articular processes of the lumbar spine may occur as an independent clinical entity. Flexion and lateral bending may produce fracture by locking of the articular processes, most easily between 4th and 5th lumbar (Koch[46]). Usually, however, this fracture is associated with partial or total dislocation in the cervical or lumbar spine, which can, as a rule, be demonstrated in a good lateral x-ray view. The most prominent signs of diastasis, of displacement, or of fracture of the articular process is a change in contour of the spine in the lateral view. The dislocated vertebra above lies in front, projecting over the lower. To avoid errors one must remember that even in the normal cervical spine there may be a slight projection of the anterior border of the body over the next lower, amounting to 3 to 4 mm. In the case of a rotatory dislocation complicating the fracture, there is increase of the intervertebral space on one side and lengthening of the shadow produced by the two displaced articular processes.

In fracture of the 5th lumbar articular process the x-ray picture shows a change of position of this vertebra to the sacrum, and the transverse process appears slightly oblique, the one on the sound side lying closer to the sacrum (Ludloff[53]).

If there is a dislocation as well as a fracture the symptoms are dominated by the dislocation; if fracture occurs without dislocation it is of little significance and the displacement is small. Clinically the fracture simulates lumbago. There may be secondary arthritic changes leading to long-continued disability.

3. Fracture of the Neural Arches (Plate XXXIX, 1, 2)

A cleft in the arches between body and articular processes may appear both in the lateral and in the diagonal ventral picture. If the crack in the laminae is small, and is behind the articular processes, it is better seen in the anteroposterior picture. If the fracture is between body and articular process, that is, near the body, the characteristic shadow of the articular process is displaced upward, forward, or downward. The clinical significance of the fracture, aside from the concomitant signs of contusion, is slight.

4. Fracture of the Spinous Processes (Plate XXXIX, 1, 2)

Only a few cases are reported in the literature, although fracture of one or several of the spinous processes of the lower cervical and upper dorsal vertebrae are not so extremely rare (Zollinger[92]). They occur usually in young people as avulsion fractures (Goetzl[22]) after the lifting of heavy loads. In one case mentioned by G. Wolff,[89] the fracture was not acquired by direct force, but by indirect violence due to extreme muscle contracture. It occurred upon lifting a heavy stone, with torsion of the head, the patient arising from the bent-over position. The mechanism is usually as follows: the thorax is fixed in forward flexion, holding its equilibrium with the muscles of the upper extremities which are lifting or setting in motion a heavy load. Trapezius and rhomboids inserting into the spinous processes exert a powerful leverage transmitted to the arm and scapula through the spine. While they are under contraction an avulsion fracture of the spines occurs, most often in the region between the 7th cervical and the 2nd dorsal. Only in one case the fracture of the 3rd dorsal vertebra was reported.

The symptoms are severe pain at the moment of injury between shoulder blades, accompanied by a cracking sound. There is great tenderness of the spines to pressure. In complete fractures, there is crepitation and abnormal mobility of the fragments, often local swelling and abnormal attitudes of the head. Pain on movement of the arms and inability to lift remains for several weeks (Kirchmayer[42]).

The treatment consists in immobilization of arm and shoulder by strapping or apparatus.

VI. POST-TRAUMATIC KYPHOSIS (KÜMMELL'S KYPHOSIS)

1. Historical and Definition

In 1891 H. Kümmell[49] in a paper on rarefying osteitis of the bodies of the vertebrae called attention to a destructive process occurring as a result of trauma, either from direct violence by a blow, or more often from indirect violence by compression. This so-called post-traumatic spondylitis or kyphosis has three stages (Kümmell[48]) : immediately following the accident there is more or less shock which soon disappears; the second stage is one of latency in which there are no symptoms and the patient feels well enough to assume his activities. After months or weeks, or even after years a third stage, that of deformity, appears with pain in the part of the spine involved.

2. Pathogenesis

The deformity appears, therefore, as remote effect of the trauma. The characteristic feature is that the latter does not appear clinically demonstrable and that there are no radiologic changes seen in the vertebra.

Before Kümmell's publication appeared Schede[69] designated the condition as a fracture of the vertebrae of slow development, followed by a breaking down of the vertebrae with secondary gibbus formation. It is to be considered that compression fractures of the vertebrae, irrespective of location occur often without any cord lesion, so that the absence of paralysis does not rule out spinal fracture (Jones[38]), and early x-ray pictures may not show demonstrable lesions, whereas, after months or years the collapse of the vertebral bodies is seen. Kümmell, however, does not admit the preexistence of a partial or total fracture of the vertebra, but assumes that nutritive or circulative disturbances of the body following the contusion are the factors which lead to a rarefying osteitis. Shortly after Kümmell's publication Verneuil[83] in 1892 described this condition as spondylite traumatique, having in mind a fracture of the spine without immediate deformity. Most observers consider the condition as a primary compression fracture without displacement or x-ray evidence, some laying particular stress upon necessity of recognizing it as an ambulatory fracture, requiring adequate immobilization (Hartwell[29, 30]).

To the group of post-traumatic spondylitis belong also the rare cases of post-tetanic compressions of the vertebral bodies. The deformity occurs early in the disease in young patients, and later in older ones (Wilhelm[87]).

The site of lesion is mostly the 4th to 7th dorsal. Compression is followed by rarefaction of the vertebral body and collapse, the deformity being well developed within five to six months.

3. Pathology (Plate XLI, 7)

Pathologic investigations on some patients dying later of intercurrent disease showed that the lumbar vertebrae were filled with small hematomas without a compression fracture being present (Ludloff[53]). The spongiosa becomes rarefied and after a time the vertebra breaks down and the gibbus appears. On the other hand, in a case reported by Weigle it appeared that compression fractures, or at least fissures, were caused by the contusion of the vertebral body, producing in the long run severe changes in contour and form.

Of interest is the behavior of the intervertebral discs. Some ascribe to the contusion of these structures an important part in the pathogenesis of the deformity (Kocher,[47] Nonne[57]). It is assumed that there is a disturbance of the intervertebral discs which cannot be seen in the x-ray picture but can be surmised from the narrowing of the intervertebral space. Others believe in a decalcification process as the immediate result of an initial fracture (Pieri,[62] Zamboni[91]). Some assume that this initial fracture is repeatedly followed by reinfractions causing a breaking down of the reparative osseous process by secondary external causes. Specimens examined by Leri[51, 52] also showed osteophytic growth in the anterior longitudinal ligaments and in the ligamenta flava protruding in the spinal canal and obstructing the intervertebral articulations. This might explain the post-traumatic medullary compression symptoms which develop slowly and progressively. Lange's experiments showed that under a certain weight the vertebral body becomes compressed but regains its former height by its own elasticity as long as the superincumbent weight does not exceed a certain amount. Beyond this amount, however, the vertebra remains compressed. This compressibility of the lower dorsal and upper lumbar vertebral bodies makes it possible that post-traumatic pathologic changes in the vertebra may occur without producing compression fractures, or an impaction, but may be sufficiently strong to produce a gradual atrophy of the spongious substance. Accordingly, the x-ray pictures taken immediately after the accident or a short time later may show completely normal findings, while after a certain time a telescoping or breaking down of the vertebral bodies and of the intervertebral discs can be demonstrated. After all, the progressiveness of the condition is most plausibly explained by assuming a gradual absorption of the bone structure, a sort of molecular necrosis accompanied by the melting down of trabeculae and an absorption of lime salts. The result is that a softened vertebral body finally yields under the weight of the superincumbent body. Small minute injuries with hemorrhage into bone and cartilage, and small minute compression fractures are generally looked upon as the anatomic basis of Kümmell's syndrome.

4. X-ray Findings

Naturally the x-ray picture, which would be of great assistance in the early stages, becomes only of value when the deformity has already made considerable progress, and positive x-ray findings in the vertebral bodies cannot be expected in the earlier stages. Of great interest are some of the x-ray pictures shown by Kümmell[48, 49] in which he demonstrated the difference in the vertebral discs in the same patient, immediately after the trauma, and later after the traumatic kyphosis had developed.

On the other hand, Froelich[18] maintains that the radiogram also discloses transverse fissures through the body of the vertebra and even avulsion or chipping off of the cortical substance without change in the height of the vertebral bodies. He concludes from his x-ray findings that, at the time of traumatism the spongious substance of the vertebral bodies undergoes multiple trabecular fractures, although there is no displacement or disalignment within the cortical substance. Only occasionally the corticalis also breaks down and then fissure fractures are seen in the radiogram. If these fractures remain undiagnosed and are not treated, they lead, under the weight of the superincumbent body, to gibbus deformity. An x-ray taken when the gibbosity appears shows diminution of the height of the body in front and lessened density of bone, while in the lateral view osteophytic growths are seen at the anterior border (Froelich[18]). In later stages the vertebral bodies become again more opaque, though the anterior flattening remains permanent, and the vertebral bodies and discs show a transformation in form and structures, adapting themselves to the increased angulation.

5. The Symptomatology

Following the acute accident the patient complains for a short time, sometimes for two or three days, of more or less violent pain in the injured section of the spine. This pain, however, disappears and the patient is enabled to follow his work and he remains free from complaint for a certain period. After a few months, however, sometimes even after a year or more, violent pain in the spine reappears and is associated, according to the seat of the lesion, with neuralgias following the distribution of the intercostal nerve, or with motor and sensory disturbances in the lower extremities. The gait becomes unsteady and staggering, and finally a deformity appears in form of a gibbus. The portion of the spine most frequently involved is the dorsal section. It is found that the most prominent vertebra and those next to it appear tender to pressure, simulating a tuberculous spondylitis in the acute stage. When the patient is suspended, the kyphos straightens out by the development of compensatory curves above and below. The gibbus itself, however, does not disappear, being due to destruction of vertebral bodies and being held rigid by the musculature of the back. Kümmell concluded that when a trauma of often slight intensity strikes the spine directly or indirectly, and when, the immediate effect of injury has worn off, after a free interval of months or even longer, a rarefying process of the vertebral bodies becomes established with loss of substance and ensuing deformity. There is never any suppuration as in tuberculous spondylitis, or any bone hypertrophy or apposition as in luetic affections, nor are there seen any changes characteristic of arthritis. Kümmell assumed that the comparatively slight trauma causes a concussion or contusion of the body of the vertebra disturbing its nutrition so that atrophy and absorption with ultimate breakdown and wedge formation of the body results. It is a purely local affair and has nothing to do with constitutional or neuropathic factors.

6. Prognosis

Experience shows that the permanent disability from Kümmell's kyphosis is not very high. In uncomplicated cases it is hardly more than 10-15 per cent. It must be conceded, however, that unfavorable cases do occur in which the disability is to be rated much higher. For compensation one may recommend a partial disability based upon one-fourth to one-third of the working capacity for one to one and a half years, but work may be resumed in part again in from four to six months after the injury, until gradually the worker's capacity increases to permanent value.

VII. THE TREATMENT OF COMPRESSION FRACTURES OF THE SPINE

The primary object of the treatment is relief of shock, prevention or reduction of displacement, manipulative or operative, relief of cord pressure by conservative or surgical means.

Secondary objectives are the treatment of bladder and rectum incontinences, of trophic and circulatory disturbances, atrophies, contractures, abscesses, sepsis, etc. (Kirchner[43]).

1. Recumbent Treatment

The mechanical principle of the treatment is hyperextension. As the pivot is chosen the site of fracture, that is, the point of the most prominent spinous process (Plate XLIII, 1).

The treatment of Wallace[85] is so devised that the lumbar spine, pelvis and lower extremities, representing the lower fragment remain fixed, while the upper spine is carried in hyperextension. The technic is as follows: large doses of morphine are given and the patient's back is immediately held immobilized to prevent further injury of the soft parts in transportation to the hospital. Here, the further mechanical treatment is carried out by means of a frame, specially constructed by Wallace, which can be attached to the side-bar of the bed.

The lower fragment, that is, the lower portion of the spine, from the site of the fracture downward, including the feet, are being held fastened to the bottom of the frame; by elevating this lower portion into the horizontal position the upper portion of the back is made to go automatically into hyperextension. In principle this treatment differs from the one on the Bradford frame in that the lumbar spine is held straight so that the flexors of the pelvis remain relaxed and no lordosis is produced (Plate XLIII, 2).

2. The Ambulatory Treatment

When the patient's back has been corrected, the spine must be immobilized until healing is complete. This is best accomplished by the application of a plaster cast, holding the spine in the position of hyperextension (Plate XLIII, 4). Wallace[85] and Markell in their plaster technic depart somewhat from the ordinary way. The patient is put on the frame so that the upper fragment is placed horizontally, the lower slants downward, producing a lumbar lordosis. A pad is applied and sewed to the stockinette, so that its lower base corresponds to the prominent vertebra. The plaster cast is applied in this position of hyperextension, and a window is cut in the back over the lumbar spine so that the upper portion of the window corresponds to the base of the pad. There are then three points of support: one at the back at the kyphosis, and two in the front, one at the upper end of the thorax and one over the pelvis. In the erect position the force of gravity and the abdominal expansion during inspiration tend to push the movable spine backward, in other words, the fixed dorsal segment is now held straight and the movable lumbar is pushed backward in a straight line. In earlier cases deformity is corrected and the patient held in correct position until healing has taken place, both in the bony parts of the spine and in the posterior muscles and ligaments (Plate XLIII, 3).

The most important element in the treatment is the early support of the back either by external splinting by means of spinal braces or plaster casts, or by internal splinting by means of osteoplastic bone operations. The advantage of the conservative treatment is a certain mobility and greater usefulness of the back (Plate XLIII, 5, 6; XLIV, 1, 2).

3. The Operative Treatment

The operation furnishes fixation in form of an internal splint. Since the first attempts of Thiebaut and Vulpius and later of Lange the operative fixation of the spine in compression fractures has been applied systematically. As early as in 1912 Quervain[64] reports a case of this kind, using the spine of the scapula as implantation material.

The results in these early cases were a considerably decreased mobility of the spine but greater stability and satisfactory function. Now the most commonly applied methods of internal splinting are the osteoplastic method of Hibbs[36] and the bone inlay method of Albee.[1a] Many observers find that Hibbs' and Albee's methods give as satisfactory results in the fracture of the spine as they do in tuberculosis (Froelich,[18] Zamboni[91]).

PLATE XLIII

Fig. 1.—Fracture of lower dorsal spine. (Traction on curved frame.)

Fig. 2.—The Wallace frame. (After Wallace.)

Fig. 3.—The Wallace-Markell cast for treatment of fractured spine. (After Wallace.)

Fig. 4.—Cast for fracture of lower dorsal and lumbar spine. Note immobilization of pelvis.

Fig. 5.—Convalescent brace for fracture of spine.

Fig. 6.—Convalescent corset.

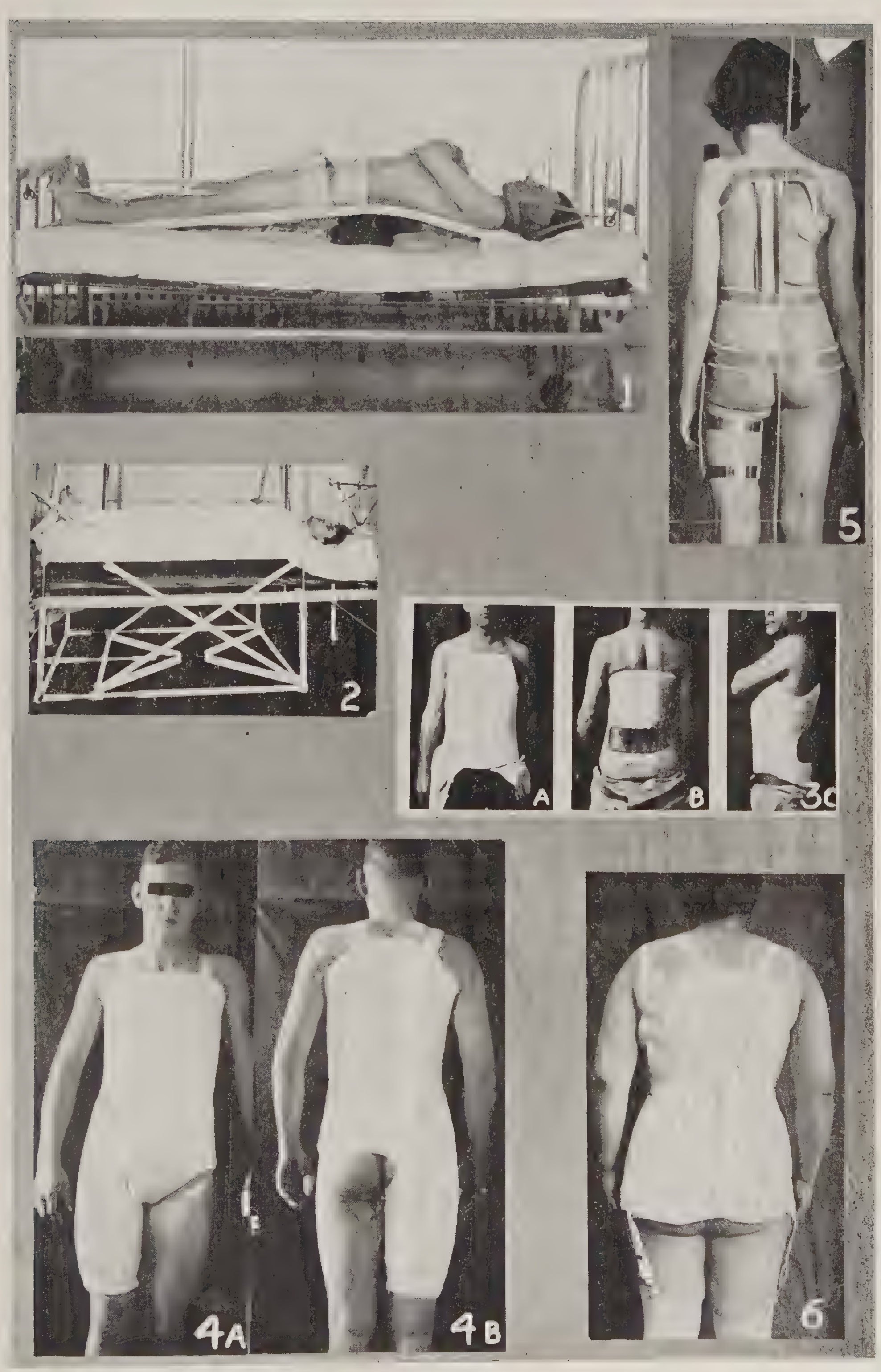


PLATE XLIII

PLATE XLIV

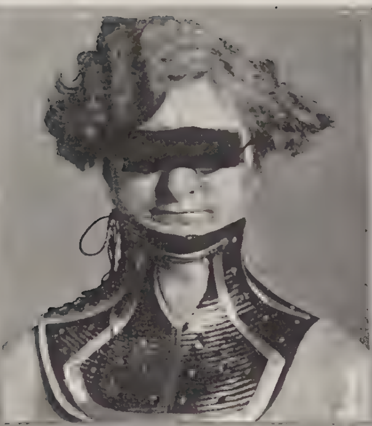
Fig. 1.—Convalescent support for fracture of cervical spine.

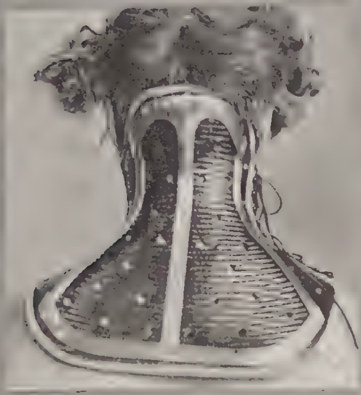
Fig. 2.—Posterior view of Fig. 1.

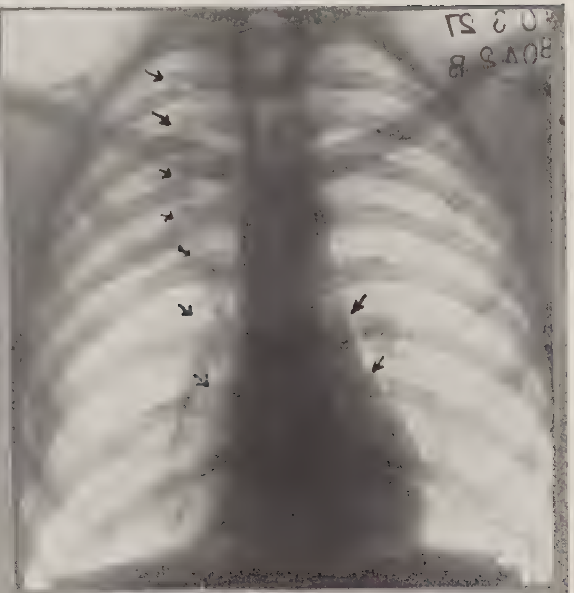
Fig. 3.—Showing anatomy of sternum, anterior thoracic and anterior abdominal walls. Effect of rectus abdominis upon distention fracture of sternum. (After Braus.)

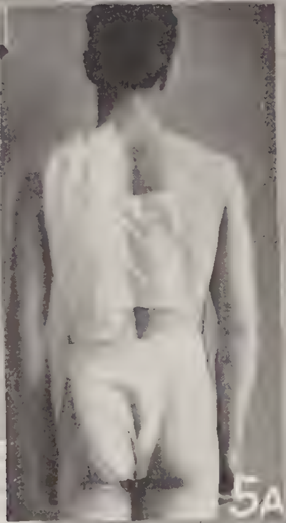
Fig. 4.—Fractures of 3rd-9th ribs by indirect violence (automobile accident).

Fig. 5.—Patient strapped for fractured ribs.









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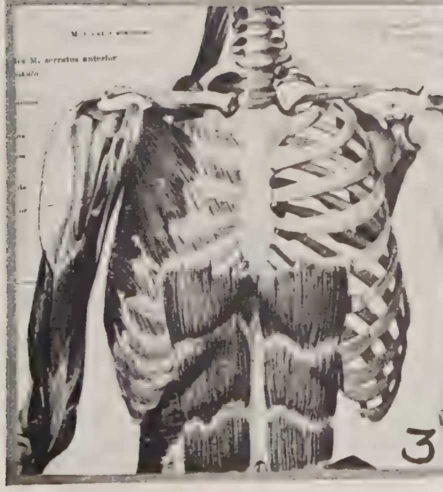

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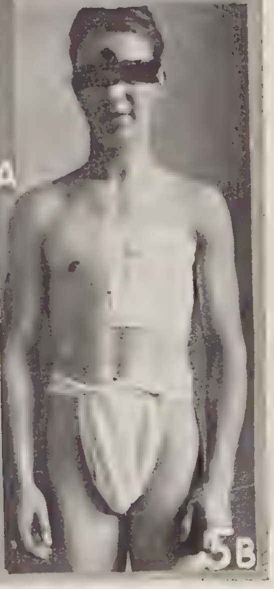

5B

PLATE XLIV

a. Indications.—It is not easy to find the limits of indications for surgical intervention in traumatic spondylitis. The series of end-results reported by Wallace[85] and Rogers[68] as well as that of Osgood,[59] show that the conservative treatment is attended by excellent results. Full functional return may be expected after four to six months of recumbency and hyperextension with the spine immobilized in a shell or jacket. Osgood finds nothing to indicate that the average case of compression fracture needs operative procedures.

The indications for operation are, therefore, to be made upon the basis of exceptional situations. Brackett, Mixter, and Wilson[4] (1918) formulated the indications for operation as follows: abnormal mobility, increasing deformity, and extensive fracture of body and laminae; also in cases in which ankylosation is retarded, operation may serve as a time-saving measure. Zamboni[91] believes that surgical intervention finds an indication in the persistence of subjective symptoms after the appearance of the gibbus, and especially of pain and fatigue, otherwise impossible of control; for instance, in cases where the new-formed osseous tissue from periosteal fragments produces a constant irritating effect, and where surgical interference alone could produce the absolute immobilization necessary for the subsidence of pain.

Kleinberg[44] finds the operation indicated when jacket or brace prove insufficient, or when it is important to shorten the period of convalescence, and he believes that operative treatment should not wait for the failure of the conservative treatment as has been the practice in the past. He maintains that the operation shortens the period of convalescence and disability to a degree worth while and that a more rapid healing of the fracture takes place.

The degree of deformity and its rate of progress is also a factor which must be considered before operation is advised. From our studies in spinal tuberculosis we know that the ultimate fate of the graft, so far as its bone-splinting and weight-supporting quality is concerned, does not always harmonize with the expected mechanical function. We know that in an angular kyphosis an absorption of the graft at the point of angulation is likely to occur under the stress of weight bearing. Anatomic and biologic investigations prove that absorption of the inlay graft occurs the sooner the more tension stress is placed upon it. In Kümmell's kyphosis the conditions are more favorable than in tuberculosis, because the time required for such absorption under tension stress, is longer than that ordinarily required for the healing of the fracture deformity. From the viewpoint of permanency of the graft there is, therefore, not so much uncertainty of the fusion operation in spinal fracture or post-traumatic kyphosis as there is in tuberculosis.

b. Technic.—The field of fusion should include, at least, six vertebrae, three above and three below the angulation. The stiffness and stability of the spine ultimately obtained by the operation is considerable. If the dorsal spine is affected the internal fixation is a most desirable form of treatment, since the dorsal spine, normally, has very little motion. On the other hand, in lesions of a vertebra of the cervical or lumbar region the operative treatment completely immobilizes this part of the spine which normally is very movable, and this must be taken into consideration especially since the majority of cases are laborers to whom free mobility of the spine is of the greatest importance (see Chapter VI).

4. Duration and Statistics

The duration of convalescence under conservative treatment is one and a half to two years. The duration of convalescence after operation for fracture of the spine is six months to a year (Kleinberg[44]). Comparing the results of conservative and operative treatment as to duration and disability, Cleary[6] finds also that the fusion operation shortens convalescence; disability in operated cases lasted eight to twelve months with 30 to 40 per cent permanent disability, while in conservatively treated cases the period of disability was slightly longer.

VIII. TREATMENT OF COMPRESSION PARALYSIS

The injuries to the cord complicating fractures of the spinal column are classified by Kocher[47] as follows: (1) contusion with intra- and extramedullary hemorrhage. The site of this hemorrhage is at the level of the greatest lesion, usually in the cervical region. If there are no irritative roots symptoms, there is little involvement of sensibility compared with that of mobility. The sensibility becomes rapidly restored, there is no hyperesthesia and no radiating pain. (2) Cord pressure with hemorrhage. Here we have motor paralysis, increased knee reflexes, radiating pain, tetanic contractures, paraesthesias, tenesmus, etc. (3) Cord lesions with compression. There is involvement of the roots, sensory disturbances, anesthesias, paraesthesias, analgesias together with motor symptoms. There are increased reflexes and urinary retention. (4) Unilateral cord lesions with motor paralysis and atrophy, Brown-Sequard syndrome, vasomotor paralysis, hyperesthesia, increased reflexes, pain, spasticity of the affected side.

Frazier[17] and Allen[1] believe that the edema seen in the cord in patients dying later, is most extensive within the area of blood extravasation, and is essentially progressive and destructive in its tendency, so that nerve tracts which have escaped destruction by the primary injury may be destroyed later by edema.

1. Cord Drainage

The experimental observations of Allen[1, 2] have some bearing upon the indication of laminectomy as a relief measure in traumatic paralysis and especially in Kümmell's kyphosis. Allen found that after a laminectomy had been performed without opening the dura, there was a certain maximum amount of impact which could be transmitted to the spine and from which the spinal cord of the animal could still recover with normal motor function, and without further operative procedure. There was also a certain amount of impact from which a dog would not recover without operative procedures.

Up to 340 grams the impact could be recovered from, from anything above 450 gm. it could not, and the animal died with symptoms of complete transverse lesion of the cord unless certain operative measures were instituted. These operative measures were median longitudinal incisions 4-5 mm. long in midline through the substance of the cord. This produced sufficient drainage of blood and serum to relieve the pressure, and to prevent degeneration of the tissues. He found that fifteen minutes after the impact hemorrhage existed under the pia mater and isolated hemorrhagic foci in the gray matter. After one hour the extravasation of red blood corpuscles and the intermedullary hemorrhage had assumed greater proportions and after two hours there was found a dense ground work of red blood corpuscles in the gray matter, and the hemorrhagic areas became more contiguous. Later a swelling of the axial cylinders was observed. When this operation was performed, there was a great outpouring of blood in the injured area through incision in the cord.

Cord Pathology.—In a cord examined at autopsy, of a patient who had sustained a fracture of the 3rd cervical, Henle[33, 34] found numerous minute hemorrhages mostly in the gray matter but no ascending or descending nerve degeneration.

J. E. Thompson[82] studied the pathologic changes of the spinal cord following fracture dislocation of the spine. He first investigated the question whether or not destruction of the nervous tissues was absolute or whether it was progressive, and if it was possible to arrest progressive degeneration changes by operative methods. There are cases of complete crush of the cord in which the loss of motion is instantaneous and yet sensation is not lost until later, though as a rule, in complete transverse lesion the paralyses or anesthesias are usually defined immediately after the crush. Such cases with immediate complete motor loss and increasing anesthesia after apparently complete crush would suggest a secondary effect of edema and hemorrhage in the cord and would lend plausibility to the operative measure of cord drainage.

2. Decompression Operation

a. Indication.—Some surgeons believe in the operation for the relief of cord compression in every case and as soon as possible, hoping to find such conditions as hemorrhage, the removal of which would benefit the patient. Others oppose the operation as a routine procedure except in the rare cases where a median incision into the cord is the objective in order to relieve the cord of hemorrhage or edema.

This attitude applies, however, only to the complete cord lesions. If it were possible to distinguish with certainty between complete and incomplete transverse lesion of the cord at an early period the problem could be solved easily. At the present time, however, we are unable to decide this point and we must either wait days or weeks for some unequivocable sign, or operate early in the hope of affording relief. Many believe that waiting is the better course (Thompson[82]).

According to Norman Sharpe[73, 74] compression of the cord by disease, by bony pressure, or by edema will result not only in destruction of the injured fibers but also in permanent impairment of sound ones. He, therefore, concludes that the waiting of several days for spontaneous recovery will result in more severe impairment of the cord than has existed from the original injury. Since there is no way of knowing in a given case whether the nerve symptoms are due to irreparable damage, or to removable obstruction or other conditions remediable by surgical interference, this surgeon believes that the only logical procedure in fracture of the spine with compression symptoms, is early laminectomy. To this, however, several objections can be made (Kleinberg[44]). It can be argued that motor and sensory disturbances disappear in many cases under conservative treatment; that decompression laminectomy is often not followed by relief of motor and sensory disturbances, and that in some cases, the improvement appears so late after operation that it may be doubtful whether it is due to the latter or is spontaneous, and finally that the mortality of compression laminectomy of fractures is not inconsiderable. Kleinberg advises to wait for a few days to observe the effect of rest and sufficient support before laminectomy of the spine is undertaken. Similarly, the indications for this operation are formulated by Elsberg[16] as follows: in recent fracture of the vertebrae with injury to the cord, laminectomy should be performed only when the patient's general condition is sufficiently good and when the symptoms make it clear that the spinal cord has not been entirely crushed at the level of the injury. If the lesion has occurred in the region of the cauda equina the spinal canal should be opened as soon as the patient's general condition will permit, since the nerves of the cauda are capable of regeneration. If, on the other hand, the symptoms indicate that all cord function has not been lost and that some sensation and motor power exists, that some of the reflexes are present, then laminectomy should be performed as soon as possible. Laminectomy is likewise indicated in all fractures of the cord with persistent symptoms, where the x-ray evidence indicates that there is bone pressure upon the cord. It is also indicated in the presence of root pain due to meningeal adhesions, as these can be entirely relieved by operation. The x-ray picture, however, does not always indicate the real damage of the cord since cases with considerable displacement are observed which show very little cord damage. In addition to the situations mentioned, Mixter[54] believes that laminectomy is primarily indicated if the fracture is below the cord and the cauda equina is involved, in intradural as well as extradural hemorrhage, and also in deformity of the spine which is likely to cause compression, due to angulation.

Laminectomy is contraindicated, according to Mixter, in cases of hematomyelia, although here the clinical differentiation from compression is extremely difficult; it is contraindicated where from the history and examination the crush of the cord appears to be complete; it is also contraindicated in cases where the cord injury is so slight as to make it probable that a regression of symptoms may be expected; it is further contraindicated in the Brown-Sequard type of paralysis.

b. Statistics.—Among the largest statistics are those of Chipault[5] on 160 cases of laminectomy performed for compression of the spinal cord in fractures. Of these 25 showed cure; 33 improvement, and 65 death. Of 218 cases compiled by de Quervain[65] 30 were cured, 48 improved, 81 not changed, 4 worse, 55 died soon after operation. Fifty-eight of the 78 good results are attributed to the operation, a figure still considered high by this observer (quoted Henle[35]). In Nast-Kolb's[55] series there were 9 cures in 55 laminectomies, in 5 of which there was compression by the neural arches.

c. The Technic of Laminectomy (See Chapter VI).—The muscles of the back are dissected away from the spinous processes, Mixter[54] and Gaenslen[19a] prefer a unilateral laminectomy by stripping the muscles away from one side, keeping close to the bone. The dissection is carried out to one vertebra above and one below those of which the arches are to be removed. The spinous processes are cut away from the laminae with heavy forceps leaving them attached to the muscles on the under side and connected with each other by the interspinous ligaments. Dissection is then carried out along the laminae until the arches are completely exposed. The laminae are then cut away with ronguer forceps close to the pedicles to obtain a good exposure of the dura. Whether or not the latter is to be opened is determined by the merits of the pathologic condition. If it is to be opened the usual precautions are taken; the dura is resutured with fine silk. Then the wound is closed in the usual manner. The after-treatment consists of a period of recumbency determined by the needs of the fracture. Contentive apparatus is worn for several months after the patient has been allowed out of bed.

IX. FRACTURE OF THE STERNUM

Fractures of the sternum are the most infrequent of all fractures of the body. They constitute only $\frac{5}{100}$ of 1 per cent (according to Bruns $\frac{9}{100}$ of 1 per cent).

1. Pathogenesis (Plate XLIV, 3)

The place of fracture is usually in a line between the manubrium and the body of the sternum. The mechanism of the fracture may be compression of the sternum or distention. Distention fractures are caused by active muscle pull, or by forcible passive hyperextension of the spine such as in a fall of the body against a post, whereby the sternum is pulled apart. They may also be produced passively by vigorous acrobatic acts, such as violent swinging upon horizontal bars. Active distention fracture may be brought about by strong hyperextension of the cervical and dorsal spine under excessive contracture of the sternocleidomastoid muscle.

The majority of cases, however, are compression fractures, simple or compound, single or multiple, as coutrecoup fractures or fracture dislocations at the junction between manubrium and body of the sternum. As a rule they are associated with other bone or visceral lesions. These fractures are produced by a fall upon the head and shoulders or a forcible forward flexion of the spine which doubles or "jack-knifes" the body. In this case the body of the sternum usually overrides the manubrium. Arbuthnot Lane showed by experiments upon the cadaver that heavy blows on padded shoulders could produce a fracture of the sternum and the same mechanism of coutrecoup fracture is reported by Tarnowsky.[81] Since only in about 6 per cent of all cases there exists a bony ankylosis between the body of the sternum, and the manubrium, a genuine fracture occurs in a small number only. Most of the so-called fractures of the sternum are in reality dislocations. Ashhurst claims that the dislocations are produced by coutrecoup or muscle action, whereas the fractures proper are usually the result of direct violence.

2. Pathology

The anterior sternal ligament is usually torn and there is also a second tear within the manubrium. In distension fractures there is a diastasis of the fragments, in compression or flexion fractures the fragments override.

Injuries to the viscera of the thoracic cavity have been observed.

3. Symptoms

In fracture of the sternum the characteristic posture is the forward inclined position of the body, with careful avoidance of any movement of head, neck, and thorax. There is superficial abdominal breathing, and thoracic breathing is extremely painful. Lying upon the back is painful. A point of extreme local tenderness at the site of fracture can be readily established. It is usually at the junction between manubrium and gladiolus that the pain is most severe, increasing during inspiration, coughing, or upon attempt to move the head. Locally there is seen a bulging just above the level of the 2nd costal cartilage. There is crepitus on palpation in cases where the body overrides the manubrium.

As a rule the patients make a satisfactory recovery. The union is bony or fibrous, but several cases of ununited fracture of the sternum have been reported. Fracture deformity of the sternum must be diagnosed with caution because of the frequent occurrence of congenital malformations.

4. Treatment

The treatment consists in the reduction of the fracture by means of traction to chin and occiput. This is followed by a plaster of Paris cast or jacket with pads placed upon the site of the fracture. A steel brace which has an apron and a head support also gives sufficient immobilization. Operative treatment is indicated in cases of complication such as dyspnea from intrathoracic pressure, or abscess formation from an infected hematoma.

X. FRACTURE OF RIBS

In point of frequency fractures of the ribs occupy third place of all fractures of bones. The frequency rate is 13 per cent, being only exceeded by fractures of the femur and by fractures of the forearm (23 per cent). Since the ribs of all the skeletal parts offer the greatest surface, and since they present long thin rods and their position is a very exposed one, the frequency of fracture of the ribs can easily be understood. Nevertheless, rib fractures are comparatively rare in young individuals up to twenty years, and in children they are extremely uncommon because of the great elasticity of the thorax. With increasing age disposition to fracture also increases, and the maximum is reached between the fortieth and fiftieth year.

1. Mechanism of Rib Fracture

The mechanism of direct fracture of the rib is relatively simple. A blow to the thoracic wall, a fall upon the sharp edge of a table is able to produce it. According to the degree of the traumatizing force, the bone may fracture completely or incompletely. In either case the periosteum is involved and the fracture line may be transverse, oblique, or of irregular contour. Longitudinal fractures are rare. Greenstick fractures do occur and are situated on the concave side of the rib, fracturing the cortical texture. They also tear the periosteum, even though there may be no noticeable change on the convex side of the rib.

If the trauma is slight and subsides rapidly, the displacement of the rib fragments disappears immediately and the fragments return to normal position. In these cases the differential diagnosis between actual fracture and contusion of the thorax becomes extremely difficult. Where the trauma is more violent, the displacement of the fragments persists and they may be driven inward, tearing the pleura or lung; occasionally even the pericardium, the liver, the spleen, or kidneys may be injured by the fragments.

Indirect violence. According to Wilson and Cochrane[88] the fractures produced by indirect violence are more serious. The usual means of fracturing the rib by indirect violence is by compression of the thorax from a crushing injury. Here, the ribs give way at the point of maximum convexity, usually in front of the costal angle. In extreme cases the whole thoracic skeleton may break down and the ribs may fracture the entire length of the thorax. Such injuries occur, for instance, by being caught between the buffers of a railroad car, or by being run over. Of all the ribs, the 4th and 5th are the most frequently involved (Plate XLIV, 4). The 1st and 2nd ribs are more protected by the overlying clavicle and the 11th and 12th ribs being free ribs are short and usually escape injury.

Jones[39] (1907) reports a case of rib fracture, in an elderly patient, from whooping cough, and another case of rib fracture produced by sneezing in a woman of twenty-four years. Palfrey[61] describes ten cases, three showing crepitus and abnormal mobility of the 7th and 8th ribs in midaxillary line, all of which followed violent coughing spells due to severe tracheitis. Three other cases of fracture of ribs due to coughing are reported by Webb and Gilbert.[86] In many cases the rib is fractured by muscle pull, and instances have been reported occurring during childbirth. Up to 1924 only fifty-six cases were reported of rib fractures due to violent muscle action, and only thirteen of these due to other causes than sneezing or coughing (Kleiner[45]). These fractures are usually facilitated by the degenerative changes in the bone. Traumatic separation at the costocartilaginous junction usually occurs in patients with degenerative changes in the cartilage, otherwise fracture of the rib is the rule (Oudard and Jean[60]). Fracture of cartilaginous portions usually occurs at 8th or 9th rib (Keen).

Indirect rib fractures have also been observed from lifting of heavy loads (Cohn[7]), or after sudden twist of the body (Dubs[14]). Haubensack[31] gives the following tabulation of injuries producing fractures of the ribs: direct blow 28 per cent, being run over 2.3 per cent, slipping on the floor and falling against an object 34 per cent, simple slipping 8 per cent, muscle pull 3.3 per cent, other injuries 22.3 per cent.

2. Symptoms

The description of the trauma, the type of pain, its location, etc., makes the diagnosis quite easy. The suffering is severe because it is affected by respiratory movement, and the character of breathing is accordingly altered; it becomes short and shallow due to the efforts of the muscles to protect the affected side of the thorax. The patient usually feels more comfortable when sitting than when lying down. The most constant finding is the local tenderness on pressure and the pain at the seat of the injury. There is also pain on anteroposterior compression of the chest.

Ecchymosis and suffusion are found in a considerable number of cases. Sometimes a sharp click is heard on forced inspiration, or may be heard through a stethoscope. Crepitation is rather the exception, it being found, according to Hausensack only in 17 per cent; often one must be content with establishing the local and indirect pressure pain over the affected rib. Important for the diagnosis is particularly the very intense referred pain from chest compression described above. Since the trauma produces a more or less extensive contusion of the thorax it becomes difficult to differentiate between contusion and fracture unless definite signs of fracture can be established.

As a rule callus formation of a fractured rib is slight. Normally the callus is formed as early as eight to twelve days after the accident. Fusion between two ribs by callus formation is rare, so are also exostoses.

Complete cure in uncomplicated cases can be expected in three to four weeks, and in simple infractions or subperiosteal fractures even much earlier.

3. Complications

Such complications as arise directly from injuries of the thoracic viscera by sharp fragments have already been mentioned. Injuries to the pleura and lung cause hemothorax, pneumothorax, hemoptysis, or emphysema. Subcutaneous emphysema is not infrequent and its presence indicates a concomitant injury of the lung. It can be readily recognized by the fine crackling sensation which the hand feels as it is pressed against the surface of the skin.

All in all, permanent complications after fracture of the rib are the exception. Even people suffering from chronic diseases of the pleura or the lungs usually get well in a surprisingly short time.

According to the statistics of Haubensack[31] complications are found in 13 per cent of the cases, while 87 per cent heal without any difficulties. The most frequent complication is traumatic pleurisy, but this is usually only of short duration, and is limited to the region of the trauma. There may be adhesions of the parietal and visceral pleura. The pleurisy is usually a dry one; exudative or purulent forms are the exception. Hemoptoe is often seen as the result of the rupture of the small vessels of the lungs, not necessarily due to the contusion of the thorax or direct injury by the fragments. On the other hand, pneumonia and bronchitis occur not infrequently in people with chronic diseases of the lungs, such as asthma, emphysema, or chronic bronchitis.

Another cause for disability following fracture of the rib is the persistence of pain at the site of the fracture. True intercostal neuralgia following contusion of the thorax, or a fracture of the ribs, can only be assumed if there is either pressure of the callus upon the intercostal nerve or an inflammation of the nerve following contusion. In this case the pressure point is located exactly along the run of the nerve or it appears at the three principal pressure points of the nerves, that is: next to the spine, in the middle, and in front of the thorax. Haubensack believes that true intercostal neuralgia as the result of fracture of the rib is very rare. It is very doubtful whether a post-traumatic tuberculosis can develop from fracture of the ribs, and the same is true of tumor or tuberculosis of the rib itself.

The prognosis of rib fracture is good. In the large material of Haubensack embracing 1166 cases, prompt healing occurred in 98.5 per cent and death in only 1.5 per cent.

4. Treatment

Relief from pain can usually be secured by immobilization obtained by simple retentive measures. Satisfactory immobilization can be carried out by adhesive plaster strapping. The straps should be applied to the affected side of the thorax, the other side must be left uncovered so as to facilitate free breathing. Strapping on both sides would defeat the purpose of immobilizing the affected side alone. Straps of adhesive two inches wide and of sufficient length are applied to reach more than half way around the chest. They are applied to overlap each other. The straps should reach from the sternum around the affected side to the spine, then should go a hand's breadth over to the well side (Plate XLIV, 5). It has been recommended to apply these adhesive straps in deep inspiration. Operative interference is occasionally necessary in comminuted fracture where the fragments enter the chest. For intercostal neuralgia, fixation, massage, heat, breathing exercises, etc., are recommended.

XI. COMMENT ON CHAPTER IV: FRACTURE AND DISLOCATION DEFORMITIES

The deformity, as such, becomes a matter of secondary consideration even in old fracture and dislocation deformities of the spine. In dislocations a prominent feature is the early loss of reducibility; successfully reduced dislocations of the cervical spine are still the exception rather than the rule. The principal reason for this is, failure in early diagnosis. In fracture deformities of the spine (compression fractures) the conservative treatment is still advocated as the method of choice by the majority of surgeons, although there is a growing tendency toward primary fusion operations. It is usually the complications which cast the decision for operative interference: persistent pain, root symptoms, cord compression.

The indication for decompression operation (laminectomy) can be epitomized as follows: early operation after the shock has passed, in cases of incomplete crush of the cord; later operation in cases of progressive symptoms; operation in all cases of injury to the cauda equina.

Fracture deformities of the apophyses of the vertebral column are of lesser significance. Fractures of the transverse processes are of secondary importance compared with the primary injuries to the soft tissues of the back. Fractures of the arches and the articular processes are of orthopedic interest in persistence of pain or root symptoms. This persistence occasionally constitutes operative indications. So do also the crush fractures of the articular processes and the intervertebral articulations, especially in the lumbar and lumbosacral region.

Fracture of the coccyx becomes an operative problem when the symptoms point definitely to that region and have been dissociated from concomitant symptoms due to sacrolumbar or sacroiliac disturbances. Uncomplicated compression fractures of the vertebral bodies and of the processes furnish a large contingent of diagnostic errors. The bone injury is often overshadowed by the signs of primary soft part lesion. Persistence of subjective complaints and disability beyond the period required for soft tissue repair should arouse suspicion.

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CHAPTER V

LOW BACK PAIN

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VIII. Comment on Chapter V: Low Back Pain

DEFINITION AND CLASSIFICATION

Few situations in orthopedic surgery equal or surpass in diagnostic difficulties the syndrome of the lumbar and sacral regions, commonly designated as low back pain.

The reason for this difficulty lies in the very wide symptomatologic significance of this type of pain. It shares with the symptom of headache the distinction of having almost unlimited possibilities of interpretation. Low back pain is so frequent and so disabling that a good deal of attention has been paid to it by the profession of all times, but clearness and comprehension has been brought into the subject only by more recent investigations. For practical reasons it will be most opportune to divide the large material in cases in which low back pain is symptomatic of other underlying diseases: the symptomatic low back pain; and in cases in which the low back pain is an essential symptom of a regional disturbance of the skeleton or of its immediate surroundings: the idiopathic low back pain.

I. SYMPTOMATIC LOW BACK PAIN

1. Gastrointestinal

In disturbances of the digestive tract low back pain is encountered as referred symptom: in appendicitis or in involvement of retroperitoneal glands, in hemorrhoids, in diseases of the colon, of the rectum, in peritonitis as well as in hernias and adhesions of all kinds.

2. Genitourinary

In the genitourinary system low back pain is found in pyelitis, in stones, and tumors of the genitourinary tract, in renal disease, in diseases of the ovaries, of the uterus, in malpositions of the uterus, in adhesions, and in diseases or tumors of the prostate gland. The last mentioned are especially interesting from the viewpoint of differential diagnosis.

According to the investigations of Young,[102] Gerachty, and Stevens,[101] pain in the back simulating lumbago, sciatica, and sacroiliac disease, or renal colic, may be due to chronic inflammation of the prostate. In long-standing cases of prostatitis and spermatocystitis one finds frequently adhesions which bind these organs together with neighboring structures; and referred pain may be caused by the pull or pressure of these adhesions upon the nerves (Baker[6]). Cases have been observed in which immediately after infection of the seminal vessels intense pain appeared in the sacroiliac joint of the same side. However, not all cases of prostatitis and spermatocystitis complain of back pain, and, on the other hand, many cases of sacroiliac disease may, at the same time, suffer independently from affections of the male pelvic organs.

Low back pain also occurs in carcinoma of the prostate. Young,[102] Gerachty and Stevens[101] observed among 111 cases of carcinoma of the prostate, low back pain in six, and pain referred to the sciatic nerve in three cases, making the incidence of low back pain about 8 per cent. Prostate and seminal vesicles receive fibers from the 10th, 11th and 12th dorsal, as well as from the five lumbar and the upper three sacral segments, which accounts for the wide distribution of pain when these organs are involved. Prostatic pain is usually of referred character simulating lumbago, sacroiliac disease, sciatica, or other afflictions of the bony and ligamentous structures of the lower spine and pelvis. It is characteristic for referred pain, however, that it is not dependent upon motion or posture of the body as is the local or idiopathic low back pain.

3. Gynecologic

Of greatest importance is the recognition of low back pain in gynecologic conditions. There is still a great deal of uncertainty as to the relation of low back pain to pathologic changes of the female pelvic organs. It is commonly supposed that of the various pelvic abnormalities malpositions of the uterus are the most important. Later investigations, however, have considerably changed the general opinion of the influence of displacement of the uterus upon low back pain. In his book on differential diagnosis Cabot states that a most careful study of backache and other pain in relation to pelvic disease, showed that there is no type of backache or reflex pain which can reasonably be referred to pelvic disease, and that all types of pain in the back, head, and extremities, occur with equal frequency with or without pelvic disease. On the other hand, Graves,[43, 44] from an analysis of five hundred successive cases of retroversion operated upon at the Brooklyn Free Hospital finds that 76 per cent of these suffered with low back pain, and of the cases operated, 86 per cent were entirely cured or greatly relieved of this particular symptom. So, it seems evident that a relation exists, at least between retroversion and backache. In order to determine further whether this backache was the result of the displacement of the uterus alone or of a complicated inflammatory condition of the pelvis, an analysis of another one hundred cases of retroversion without pelvic inflammation disclosed the fact that sixty of these complained of low back pain against seventy-six in the larger series with pelvic disease; and of the latter 95 per cent stated that they were either cured or greatly relieved of back pain after operation, which would indicate that pelvic inflammation associated with retroposition of the uterus definitely increases the incidence of the back symptoms.

As far as the tumors of the pelvis are concerned a study of anteversion produced by pelvic tumors showed that some tumors, completely filling the pelvis and pressing the uterus forward, are not associated with back pain; this would make it appear that the low back pain is rather caused by the backward displacement of the uterus than by the presence of the tumor.

Back pain associated with retroversion is most typically seen in cases which also show a retroflexion of the uterus, that is, where this organ is bent upon itself. The uterine back pain is distinctly confined to the sacrum and lower lumbar regions and does not, as is sometimes believed, radiate over other portions of the spine, or the shoulders or the back of the neck. One-sided low back pain may also be caused by pelvic tumors pressing upon nerve trunks. Cancer of the pelvis is usually painless at first, according to Graves, but in the later stages it produces most excruciating forms of backache, an unfailing sign of the extension of the disease into the pelvic cellular tissue and to the regional lymph glands.

4. Diseases of the Central Nervous System

To this group belong tabes, meningitis, syringomyelia, lateral sclerosis and tumors of the cord as well as neuritis. Severe pain in the back of sudden onset accompanied by muscle spasms of the back muscles may also be caused by hemorrhage into the meninges or into the substance of the cord. In pachymeningitis externa the irritation of the sensory roots by compression may produce a local pain in the back mostly of radiating character associated with rigidity and tenderness of the spine, and aggravated by movement. There is often observed a generalized hyperesthesia of the back with radiating pain in the early stages of acute poliomyelitis. Low back pain is also seen in syringomyelia with marked curvature of the spine. In multiple neuritis pain in the back is likewise an early symptom.

5. Tumors

Low back pain is occasionally due to tumors of the vertebral column or the spinal cord. The pain is usually very intense, often associated with symptoms of motor irritation. This is particularly the case in tumors of the cord or cauda. Low back pain in metastatic tumors, for instance carcinoma following cancer of the breast or of the uterus is observed. It is also a prominent symptom in primary malignant tumors such as sarcoma and myeloma, and is characterized by its early appearance and uncontrollable character. Occasionally cases of osteoma or osteochondroma of the spine will produce radicular or pressure symptoms in the lower back.

6. Peripheral Nerve Disturbances

Sciatica, one of the most common complications found in association with low back pain is most frequently a symptom secondary to local disorders in the lumbar and sacral regions. There is, however, no reason to discard it entirely as a clinical entity. In order to recognize an idiopathic sciatic neuritis, other neuritic signs such as hyperesthesia, anesthesia, paraesthesia, atrophy of the muscles with paralysis, electrical reaction of nerve degeneration, trophic symptoms, etc., should be present. If sciatic pain is due to pressure of nerves or nerve roots only, degeneration is absent and the nerve trunk lower down does not appear tender to pressure.

7. General Infectious Diseases

Among these there may be mentioned especially typhoid, the acute exanthema, influenza, acute articular rheumatism, septicemia, as conditions in which low back pain plays an important part.

8. Infections of Spinal Column

Of the inflammatory conditions of the spine itself chronic osteomyelitis, typhoid spine, and tuberculosis of the spine, acute and chronic forms of arthritis, including osteoarthritis, gonorrheal arthritis, must be considered. The arthropathies of the spine following tabes and syringomyelia occasionally produce pain radiating into the lumbar and sacral regions.

II. THE IDIOPATHIC LOW BACK PAIN OF MECHANICAL ORIGIN

Here again a distinction should be made between injury resulting in a definite, demonstrable discontinuity or disalignment of bone and joints, that is, fracture dislocations, crush fracture of the vertebrae or their appendages and processes, types that have been discussed in the previous chapter; and the group of injuries to the soft structures which compose the lumbosacral and sacroiliac regions; this constitutes the great majority of low back pain due to extrinsic or mechanical causes.

Herndon[50] finds that of mechanical injuries to the spine 66 per cent concern the soft structures of the lumbosacral and sacroiliac sections. Of these 13 per cent are contusions or injuries to the musculature, and 53 per cent sprains or injuries to the ligamentous apparatus. Key[54] finds that of all cases complaining of low back pain 60 per cent are due to strains of the lumbosacral and sacroiliac junctions.

1. Definition of Sprain

Sprains are anatomic changes in the continuity or the physical integrity of the ligamentous structures, produced by mechanical forces sufficiently intense and of appropriate direction to overcome the resistance of these structures. The function of the ligaments is to restrain motion in a near-by articulation; for instance, the ligamenta sacrospinosum and sacrotuberosum restrain motion in the sacroiliac junction by preventing a separation of the sacrum from the tuber ossis ischii. In a similar manner the iliolumbar ligament restrains movement between the 5th lumbar and the sacrum, preventing a forward displacement of the 5th lumbar upon the sacrum. So also the anterior longitudinal ligament restrains hyperextension in the vertebral articulations, and the sacroiliac ligamentous apparatus restrains motion between sacrum and os ilei.

The normal physiologic range of motion in the articulations determines the point at which sprain of the particular ligament begins, which is established to safeguard motion in this direction. This point designates the limit of physiologic motion; beyond it an ultraphysiologic or excess motion may be forced upon this particular joint. Whether this excess motion is caused by direct or by indirect force, it results in a detrimental stretching and straining of the safeguarding ligament. In rotatory movement of the trunk the motion may originate with the swing of arm or thorax. An excess rotatory motion may be imparted thereby, to the sacroiliac articulations. Owing to the very restricted range in this articulation, this motion cannot be properly taken care of and the result is a sprain of the articulation. We may say, then, that sprain is simply the response of the ligamentous apparatus to excess motion in the neighboring joint.

2. Pathologic Anatomy of Sprain

The anatomic corollary of sprain is a tearing or fraying of the reinforcing ligament; there is a gaping or diastasis, sometimes minute or microscopic, sometimes quite manifest; in either case a filling out of the defect with blood, granulations, and later scar tissue. The end-result is an impairment of the elasticity, resiliency, and firmness of the ligament, which finally leads to a pathologic relaxation.

3. Classification of Spines as to Susceptibility to Sprain

The external force which produces violence is in quality as well as in degree always an inconstant factor; the force must be great enough to break through the normal ligamentous safeguards. On the other hand, the spine itself, in its resistance to external violence, is likewise an inconstant element; it shows individual anatomic and pathologic variations; and on this basis it may have a predisposition to react normally or abnormally to ordinary external forces. From this point of view all spines may be classified as follows:

a. A distorting traumatizing force is applied upon a spine which is entirely normal in its construction, and has normal range of motion.

b. Owing to anatomic variations and anomalies the spine is inferior in stability and mobility to the anatomically normal spine and for this reason offers less resistance to traumatizing forces.

c. Stability and mobility of the spine are impaired and restricted by pathologic conditions. This pathologically inferior spine is also predisposed to sprains.

III. ANATOMY AND MECHANICS OF LOW BACK SPRAIN

Accordingly the analysis of the mechanics leading to the disorder must be grouped under three headings, namely, one pertaining to the normal spine, one to the spine with anatomic anomalies, and one to the spine with pathologic changes.

1. The Normal Spine; Sacrolumbar and Sacroiliac Regions

We must consider in particular the rôle of the ligamentous apparatus in restraining ultraphysiologic motion. For this purpose it is simpler to divide the field grossly, first, in the sacrolumbar junction, that is, the articulation between 5th lumbar and upper end of the sacrum and the adjacent portions of the os ilei; and second, the sacroiliac region between sacrum and os ilei, including the reinforcing ligaments in the immediate vicinity, that is, the sacroiliac ligamentous apparatus as well as the ligamentum sacrospinosum and sacrotuberosum; and third, a combination of sacroiliac and sacrolumbar sprain.

a. The Lumbosacral Articulation.—The great frequency of lumbosacral sprain is explained by the fact that the lumbosacral junction represents a critical level in the mechanics of the human spine, being situated at a point of transition between the movable and immovable portion of the spinal column.

The ligamentous apparatus of this region includes the powerful anterior ligament in front of the lumbar spine and sacrum as well as the ligaments which reinforce the articulation between 5th lumbar and sacrum, and finally, the ligamentous apparatus running from the bodies and transverse processes of the 4th and 5th lumbar to the posterior border of the os ilei (Plate XLV, 1, 2). The greater or lesser freedom of motion in the articulations between 5th lumbar and sacrum depends, to a great degree, upon the position of these articulations. If they are more frontally directed, then they allow greater freedom of motion both in anteroposterior and lateral direction (Plate XLV, 3). If their direction is more sagittal, as is the case in the other segments of the lumbar spine, then mobility, especially lateral and rotatory, is restricted in this articulation (Plate XLV, 4). The firm anchorage between the last lumbar vertebra and the os ilei is represented by the iliolumbar ligament. This is of great importance for the problem of the transmission of body weight from above. It is the duty of this structure to prevent the forward sliding of the 5th lumbar upon the upper surface of the sacrum (Plate XLV, 1).

Flexion-extension movement as well as lateral motion is comparatively free in the lumbosacral articulation. The motion which is least represented is rotation, due to the arrangement of the articulation at this junction and of those in the lumbar spine above it. The only rotation possible in the lumbar spine is that between 5th lumbar and sacrum, and here it is possible only to a very limited degree. This is an important factor in the mechanogenesis of sacrolumbar sprain.

The external forces which are more likely to accumulate in the sacrolumbar junction and to lead thereby to ligamentous sprains, are those striking the body in the symmetry plane, that is, in straight back or forward direction, for instance, when the spine is forced in strong hyperextension at this junction. Among these forces there are to be mentioned gravital stresses which accentuate the normal lumbar lordosis, violent contraction of the long muscles of the back, such as in lifting or straining, or forced hyperextension movement transmitted from superincumbent weight of the body.

The strains which come in diagonal or lateral direction, because of the lesser mobility of the lumbosacral junction in this direction, are more likely to meet with a skeletal locking of the parts, and then become transmitted to the pelvis (Plate XLV, 5a).

A rotatory strain, transmitted from the upper portions of the body, still more completely passes on to the pelvis because the lumbar spine is soon locked against rotation, so that the force is transmitted and becomes effective below the level of the lumbosacral junction (Plate XLV, 5b).

b. The Sacroiliac Articulation of the Normal Spine.—This kidney-shaped articulation lying between sacrum and os ilei is extremely irregular, having many knobby elevations and corresponding indentations. For its stability it depends mainly upon the enormous ligamentous masses which extend between the nonarticulating surfaces of os ilei and sacrum: the anterior and posterior ligamentous apparatus. Against the downward descent the sacrum is secured by its wedge shape. It is not so secured, however, against descending forward into the pelvic ring and, therefore, must be held in balance and neutralized against this forward thrust as well as against rotation and lateral motion. In addition to these ligamentous masses, the ligamentum sacrospinosum and sacrotuberosum hold the lower end of the sacrum, and tuber and spine of os ischii together, thereby preventing the forward tipping of the upper portion of the sacrum (Plate XLV, 1, 2).

c. Normal X-ray Anatomy of the Sacrolumbar Articulations (Plate XLV, 3).—

The anteroposterior view shows the upper and lower contours of the usually flattened and slightly wedge-shaped body of the 5th lumbar vertebra. According to the degree of tilt of the pelvis more or less of the vertebral foramen comes into view. The articulations appear as heavy shadows at the lateral ends of the body contour. The direction of these articulations in the normal spine is in the frontal plane; changes in this direction from the frontal to a more sagittal plane are not uncommon; occasionally an asymmetry is seen, one articulation being in the frontal, the other in the sagittal plane (tropism). The spinous process of the 5th lumbar is comparatively small and the arch and laminae are slender in the anteroposterior view, the posterior or closer edges of the body of the 5th lumbar appear sharp, while the more distant anterior ones become indistinct or may disappear altogether (Schede[82]); in the lateral view the degree of angulation between 5th lumbar and sacrum is to be noted.

PLATE XLV

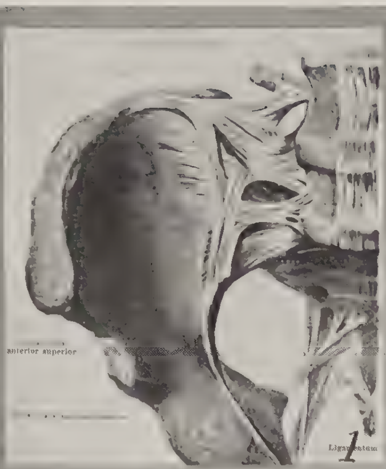
Fig. 1.—Front view of sacroiliac ligamentous apparatus and ilio-lumbar ligament. (After Spalteholtz.)

Fig. 2.—Back view of sacroiliac ligamentous apparatus, ligamentum spinoso- and tuberoso-sacrum, and sacrolumbar articulation. (After Spalteholtz.)

Fig. 3.—Normal x-ray anatomy of sacrolumbar articulations.

Fig. 4.—Normal x-ray anatomy of sacroiliac articulations. Also note sacrolumbar articulations in sagittal plane.

Fig. 5.—(A) Lateral strain imparted to sacrolumbar and sacroiliac articulations.
(B) Rotatory strain imparted to sacroiliac articulations.



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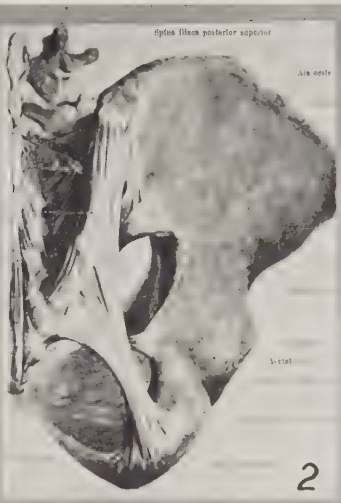

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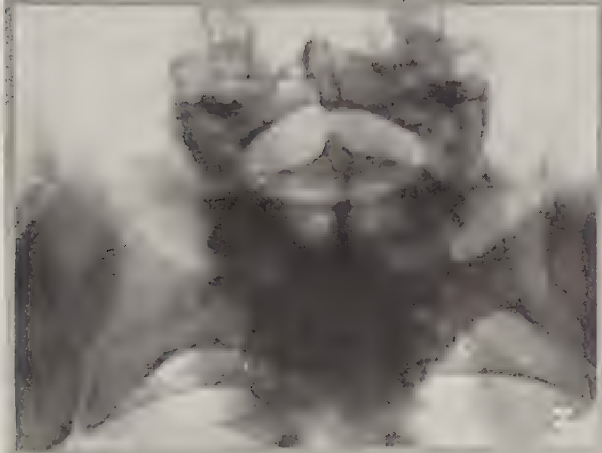

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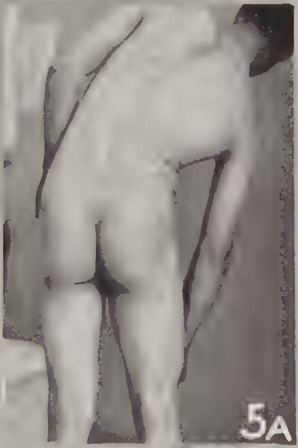
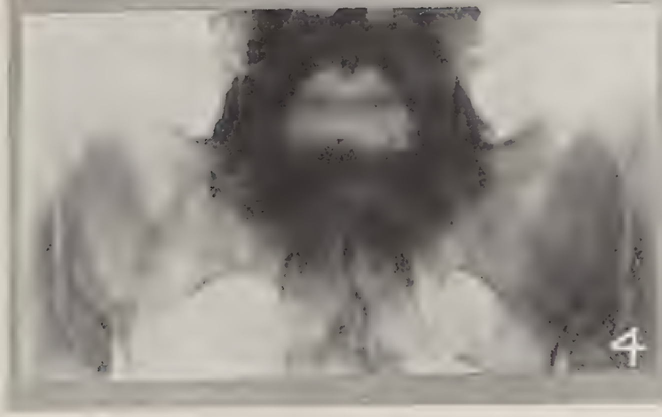


5A



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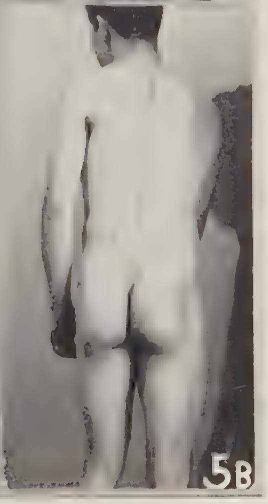


5B

PLATE XLV

d. X-ray Anatomy of Sacroiliac Articulation (Plate XLV, 4).—

The x-ray picture of the normal sacroiliac articulation shows differences according to the age. In the first years of life the normal x-ray picture of this articulation is characterized by the patency of the joint fissures, and the remarkable divergence of the bilateral joint lines downward. In the next four years the bilateral joint lines converge downward due to the growth and the curving of the os ilei. Between the fifth and tenth years the anterior joint lines become visible as well as the posterior.

Sexual differences can be seen in that the female sacrum appears wider and shorter than that of the male. The sexual differences become very much more marked from the eleventh and twelfth years on, showing in the female pelvis the greatest convexity of the anterior joint lines in the upper section of the joint, while in the male pelvis this convexity appears in the lower part (Happel[47]).

A true diastasis of the sacroiliac articulation is very rarely seen in the x-ray picture. For destructive lesions such as seen in osteomyelitis and tuberculosis, one must look especially to the upper portion of the joint. Fusion of the joint may denote a natural senile condition (bilateral), or it may be the end-product of an inflammatory process. Often arthritic changes of the joint are seen at its lower portion. At the upper portion again ossification and lime salts infiltration make their appearance, for instance, the calcification of the iliolumbar ligament.

e. Mechanogenesis of Sprain.—

(1) *Sacrolumbar Articulation.*—It appears from the foregoing remarks that forces acting in the symmetry plane, that is, anteroposteriorly, are best able to derange the sacrolumbar junction. Such forces are gravital stresses, fall upon the buttocks, violent hyperextension. If the force is not exhausted at this point, it is transmitted to the sacrum and then produces symmetrical strain upon the sacroiliac ligamentous apparatus also. Lateral strain is more likely to pass through the sacrolumbar junction and then exerts a leverage upon one or both sacroiliac articulations. Violent lateral bending which produces a rotatory effect upon the sacrum about a sagittal axis, develops shearing stresses in one or both of the sacrolumbar junctions (Plate XLV, 5a). Above all others, however, it is the rotatory strain, that is, the strain which comes from a twist or swing of the upper portions of the body and is transmitted from there to the lower extremity. Blocked by the limitations of rotation in the lumbar spine, and also by the limitation of rotation in the hip joint, if the feet are firmly planted on the ground, the full force of the rotatory momentum applies to the sacroiliac articulations and produces here symptoms of derangement (Plate XLV, 5b).

Any of these three types, namely the lateral, the anteroposterior, and the rotatory strain may be productive of sprain in both the sacroiliac junctions with or without accompanying sprain of the sacrolumbar articulation.

(2) *The Sacroiliac Articulation.*—According to Goldthwaite and Osgood[38] this articulation is by no means as stable as is generally supposed. It shows a definite, though very small amount of mobility under normal conditions. Physiologically there is a relaxation of these articulations during pregnancy and during menstruation, with loss of ligamentous tone. The relaxation associated with pregnancy is more marked and develops more rapidly, but it returns quickly to normal after delivery. In the nonpregnant relaxation the onset is not so sudden, but more insidious and troublesome. Occasionally this increased mobility in the joints can then be demonstrated (Reynolds and Newell).

Studying the relaxation in these joints during pregnancy, Cantin found that relaxation is most marked in the symphysis, while in the sacroiliac synchondrosis the changes during pregnancy are less noticeable. Yet, in all but 2 per cent of his cases, Cantin found some mobility, a condition which is not seen in nonpregnant women. This relaxation is also more frequent and more extensive in the multipara than in the primipara. Mobility between sacrum and os ilei in the sacroiliac articulations was also demonstrated in the cadaver by Goldthwaite and Osgood.[38] It is likewise known that a degree of relaxation follows the maintenance of a position in which the thighs are flexed and the sacrum in its upper portion is allowed to sag backward. Such a position exists in long recumbency, and is the explanation of the frequent backache which develops after sleep, or the usual backache after operation, where a profound relaxation of the sacroiliac articulation is produced by the anesthetic. Hence also the common way of relieving night pain in the back by stretching when first waking up, thereby drawing the lumbar spine forward (Goldthwaite[39]).

2. Spines with Anatomic Variations

Variations and developmental defects are seen in the great number of patients with painful symptoms in the lower back. It is reasonable to consider that anatomic variations in the lower lumbar joints may be a factor in causing pain by predisposing the spine to sprains and stresses more than is the case in the normally constituted spine (Palmer[76]).

We may distinguish between such anatomic variations which affect motion and thereby facilitate strain and other variations which primarily affect the stability of the spine.

a. Local Variations Affecting the Mobility of the Spine.—To understand the individual resistance of the spine to normal strains and stresses, it is especially important to consider the configuration of the 5th lumbar vertebra and its relation to neighboring structures. The normal anatomy of the 5th lumbar, as represented in the x-ray, has been considered in the previous paragraph. It is this portion of the spine which shows anatomic variations most frequently; these involve not only the shape of the vertebral body, but also the different processes, the direction of the articulations, the inclination of the pelvis, etc.

(1) *Abnormally Long Transverse Process.*—Investigating a large number of spines for congenital anomalies and malformations, Archer O'Reilly[71, 72, 73] found that the adult spine in a large percentage showed varying degrees of anomalies. The transverse process varied from simple increase in length to complete sacralization. The large transverse process of the 5th lumbar is much more common in painful backs than it is in normal adult spines, namely, in 25 per cent, while the sacralized transverse process does not necessarily always, or even in a majority of cases produce clinical symptoms. It has also been found that a long transverse process is more common in men than in women. According to Goldthwaite[37, 41] the transverse process of the 5th lumbar is in its variations a factor of great importance for the mechanical derangement of the lumbosacral articulations, and it is obvious that any anatomic variation which would restrict motion in the lumbosacral junction is likely to facilitate mechanical stress and strain at this point. In these spines we may see sprains occur from the slightest provocation and produced by forces which, under normal conditions, would be resisted without detrimental effect (Plate XLVI, 1).

(2) *Sacralization.*—Normally the transverse process is placed well in front of the posterior portion of the os ilei which it clears by a safe margin in the different motions in the lumbar articulation. Sometimes, however, there is an actual impingement between the long lateral process of the 5th lumbar and the os ilei, and in this case there is a restriction of the lateral motion. Sprain of the restricting ligaments should occur at this moment, or just before such an impingement takes place, because the ligamentous structures must become so adapted to the restricted motion, as to reach a point of stress before actual impingement. The actual contact of the transverse process against the os ilei and sacrum has been largely blamed for the clinical symptoms, but stereoscopic pictures show that actual impingement is much rarer than is generally supposed. Much depends upon the anatomic build of the pelvis. In the male pelvis the 5th lumbar is set much lower and deeper between the flare of the os ilei than in the female, where the body of the 5th lumbar rises higher between the iliac wings.

In higher degrees of variations the 5th lumbar transverse process may be so broadened that it resembles a portion of the sacral wing. It may even fuse with the sacrum and os ilei on one side or on both sides, and then one speaks of hemisacralization or double sacralization (Plate XLVI, 2, 3), in this case the 5th lumbar becomes a sacral segment and loses all individual motion; the sacrolumbar junction is then actually transferred to the articulation between the 4th and 5th lumbar vertebrae. This latter articulation, however, is usually arranged in the sagittal plane and it follows that lateral motion, and especially rotation suffers a considerable restriction by the rearrangement.

In other cases, where one finds a 5th lumbar transverse process articulating on one side and free on the other, a powerful leverage is produced on side bending, the articulating side acting as a fulcrum so that a great predisposition for sacrolumbar sprain exists.

One should not draw direct conclusions from the x-ray evidence as to the clinical significance of sacralization. Different stages of sacralization are found so frequently that additional factors must be brought in to explain the clinical syndrome. In itself, sacralization is probably rarely the cause of pain (Leri,[57, 58] Benassi[9, 10]). A syndrome of neuralgic symptoms, the so-called Bertolotti's[11] syndrome, has been recognized as being the effect of sacralization. But the presence of the broad lateral process alone is not sufficient, other factors, such as inclination of the pelvis with a greater or lesser horizontality of the sacrum must be considered as well. Casolo[19] found sacralization present in the x-ray picture in 2.5 per cent of all individuals, and symmetrical sacralization much more common than asymmetrical. According to this observer 58 per cent of the individuals showing x-ray evidence of sacralization had neuralgic symptoms in the form of Bertolotti's syndrome (see later). In many cases one notices the x-ray findings of sacralization associated with pathologic changes; for instance, the calcification of ligaments as evidence of infectious arthritis (Doub[28]).

Actual contact of bone, or articulations between 5th lumbar transverse process and pelvic bones can only be demonstrated in the stereoscopic x-ray picture, and on these grounds only a positive diagnosis of sacralization can be made. Having examined a series of sacrolumbar regions, Benassi[9, 10] finds that the percentage of all patients who complained of pain in the lower back and lower dorsal region, but who showed no impingement or contact, was 46 per cent.

Sacralization in the anatomic sense is obviously much less frequent than the so-called pseudosacralization or pseudocontact as revealed in the x-ray picture (Plate XLVI, 4). On the other hand, even in cases in which there is not actual contact, but merely a pseudocontact, one may note symptoms of pressure.

The clinical significance of the phenomenon of sacralization or actual contact is better understood if other signs of developmental anomalies and arrest often accompanying this variation of the 5th lumbar vertebra are considered. There is frequently a lack of fusion of the laminae and other malformations which point to a deeper and more developmental nature of the anomaly. According to Benassi two types of sacralization may be distinguished: (1) the true sacralization which shows the so-called syndrome of Bertolotti (See Chapter on Clinical Symptoms). There may be complete, actual contact with fusion of the 5th lumbar with the sacrum or os ilei, or incomplete contact with the sacrum, bilaterally or unilaterally; (2) the pseudosacralization which consists merely in excessive development of the 5th lumbar process without actual contact or fusion; this also may be unilateral or bilateral.

In another group of cases a condition of lumbarization may exist, the first sacral vertebra being more or less incompletely differentiated as a lumbar segment (Plate XLVI, 5). While sacralization might explain compression symptoms of nerve trunk, it is hard to explain these symptoms in cases where the first sacral segment is transformed into a lumbar vertebra. But cases of lumbarized sacral vertebrae with a syndrome of nerve compression are re-

PLATE XLVI

Fig. 1.—Note long transverse process of 5th lumbar. Note also one sacrolumbar articulation in the frontal and the other in the sagittal plane: tropism.

Fig. 2.—Note hemisacralization and long transverse process on the other side.

Fig. 3.—Double sacralization.

Fig. 4.—Pseudosacralization. The transverse processes do not actually touch.

Fig. 5.—Lumbarization of the 1st sacral segment. Note independent wings.

Fig. 6.—Spina bifida occulta. Note complete absence of all sacral arches. (No symptoms.)

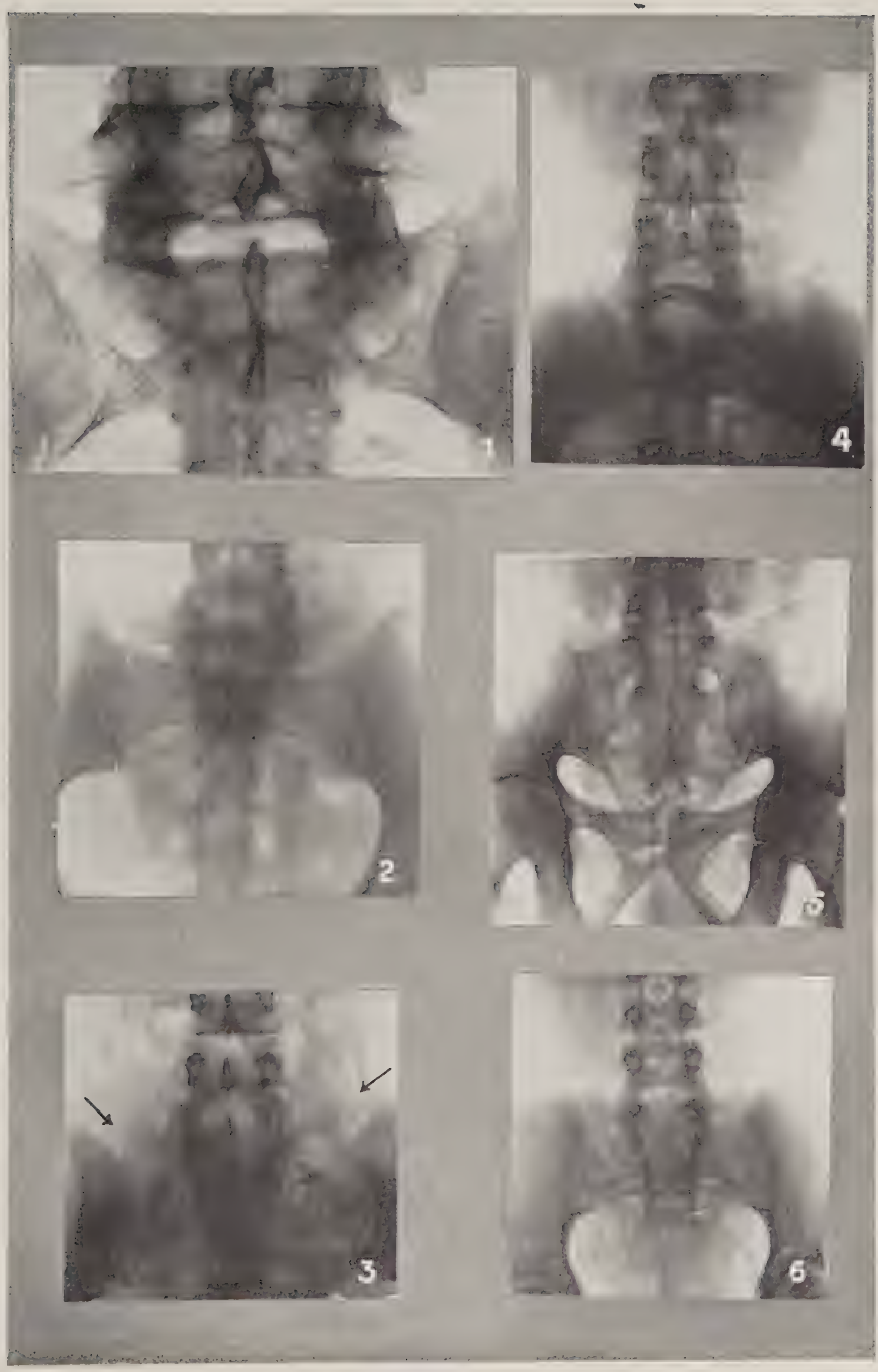


PLATE XLVI

ported; they usually start to produce symptoms in the 3rd decade and rarely before the 18th year (Benassi[9, 10]).

(3) *Anomalies of the Intervertebral Articulations of the Lumbosacral Junction Restricting Mobility.*—In the lumbosacral articulations one may distinguish the type in which there is the usual arrangement in the frontal plane, which, according to Goldthwaite[37, 41] makes for an unstable articulation (Plate XLV, 3). In other types the 5th lumbar articulations show more of the character of the other lumbar articulations, that is, they are arranged in sagittal direction making the joint more stable (Plate XLV, 4). In the latter case, however, motion is restricted. Between these two types are many transitional forms (Plate XLVI, 1, tropism; Plate XLVII, 5).

All these localized anatomic variations in formation and arrangement of articulations, the increased leverage resulting from an impinging transverse process, the shifting of the centers of motion due to sacralization or hemisacralization are factors which produce a general predisposition of the spine to respond to normal dynamic impulses by abnormal reaction and, consequently, to favor the occurrence of stresses or strains.

b. Anatomic Variations of Lumbosacral and Sacroiliac Junctions Affecting Stability of the Spine.—

(1) *Clefts and Pseudarthrosis.*—To this group belongs the incomplete formation of the laminae in the lumbar and sacral regions, as well as the cases of anomalous articulations existing between the pedicles and arches as a result of nonunion of ossification centers (spondylolysis). The latter anomalies are the anatomical basis for a spondylolisthesis or forward gliding of the 5th lumbar vertebra upon the sacrum (Plate XLVII, 1, 2a, b). The former anomalies are observed in the so-called spina bifida occulta, and consist in the failure of the neural arches to close in the middle because the ossification centers of both laminal halves do not become united (Plate XLVI, 6). Such clefts of the 4th and 5th lumbar and 1st and 2nd sacral segments (spina bifida occulta) carry with them also a lack of development of the ligamentous supporting apparatus between the 5th lumbar and the sacrum. The spine is thereby rendered potentially weak and subject to sprains, not because of inherent restriction of motion, but because of the maldevelopment of the ligamentous apparatus which does not function properly as a safeguard against excess motion.

c. General Anatomic Variations Affecting Mobility and Stability in the Lower Back.—

(1) *Anatomic Types.*—It is obvious that the greater the restriction imposed upon the spine by virtue of its particular anatomic makeup, the greater are also the possibilities that such motion may be transgressed in the ordinary functions of the body and the greater, consequently, the danger of sprain. Some spines show a general anatomic type and build which facilitates the occurrence of static stresses. Here belong, above all, the long and narrow backs

seen more often in women than in men; the backs in which the lumbar spine is set up high so that the sacrum is of greater length than normal. Here also belong the backs with the flat lumbar spines, which, generally endowed with poor musculature, are in poor condition to resist strains transmitted to this region from above.

(2) *Hollow Back, Horizontal Sacrum.*—Another type of back which predisposes to strain is the hollow back. It shows an increased lumbar lordosis and a sacrum which is more or less horizontal, the pelvic inclination being greatly increased. This increased inclination of the 5th lumbar with horizontality of the sacrum produces a marked foreshortening of the 5th lumbar body in the anteroposterior x-ray view. In the lateral view it appears decidedly wedge shape but in full contact with the upper surface of the sacrum (Lewald[59]). (Plate XLVII, 3.) It is these backs which are especially prone to develop abnormal forward shearing stresses between the 5th lumbar and the sacrum (Von Lackum[96]). By some observers this type is classified as a forerunner or a beginning of a spondylolisthesis, but these hollow backs do not show true displacement between the 5th lumbar and the sacrum which is the pathognomic point in spondylolisthesis, nor do they show abnormal articulations between neural arches and the pedicles of the vertebrae. In the hollow back as well as in true spondylolisthesis there is a great deal of weakness of the ligamentous apparatus at the lumbosacral junction, and in the hollow back there is also a great deal of abnormal stress upon the iliolumbar and sacroiliac ligamentous apparatus.

(3) *General Static Factors.*—Attention also must be called to static disalignments in different regions of the body, as causing back pain by transmitting stresses. Here belong the frequent cases of static foot strain, ankle valgus, knee strain, faulty posture, defective weight bearing line, etc. (Osgood[74]).

3. Pathologic Changes of Sacroiliac and Sacrolumbar Articulations Predisposing to Sprain

To this group belong the traumatic and inflammatory-arthritic conditions which involve or include the sacrolumbar or sacroiliac regions. More frequently these are cases in which a generalized osteoarthritis of the spine forms the basis for sacrolumbar and sacroiliac strains (Plate XLVII, 4). Here also belong the cases of fusion or synostosis of this articulation following inflammatory destruction. The loss of motion in neighboring articulations concentrates the mechanical strain in the sacrolumbar and sacroiliac regions, and for this reason these spines appear more susceptible to sprains than normal spines in which the dynamic stresses can be properly intercepted and distributed.

In many instances the x-ray picture reveals inflammatory or degenerative changes of soft structures in conjunction with arthritic changes of the spine; for instance, one sees ossification and calcification of ligaments accompanying arthritic changes of the sacroiliac or sacrolumbar junctions (Doub[28]).

PLATE XLVII

Fig. 1.—Spondylolisthesis. Note forward displacement of 5th lumbar over sacrum.

Fig. 2.—(A) Spondylolisthetic patient—back view.
(B) Same patient—side view.

Fig. 3.—Horizontal sacrum. Forward shearing stress.

Fig. 4.—Arthritic spine.—Symptoms of lumbosacral strain present in this patient. Concentration of stresses at this junction.

Fig. 5.—Tropism of lumbosacral articulations. One in frontal and one in sagittal plane.

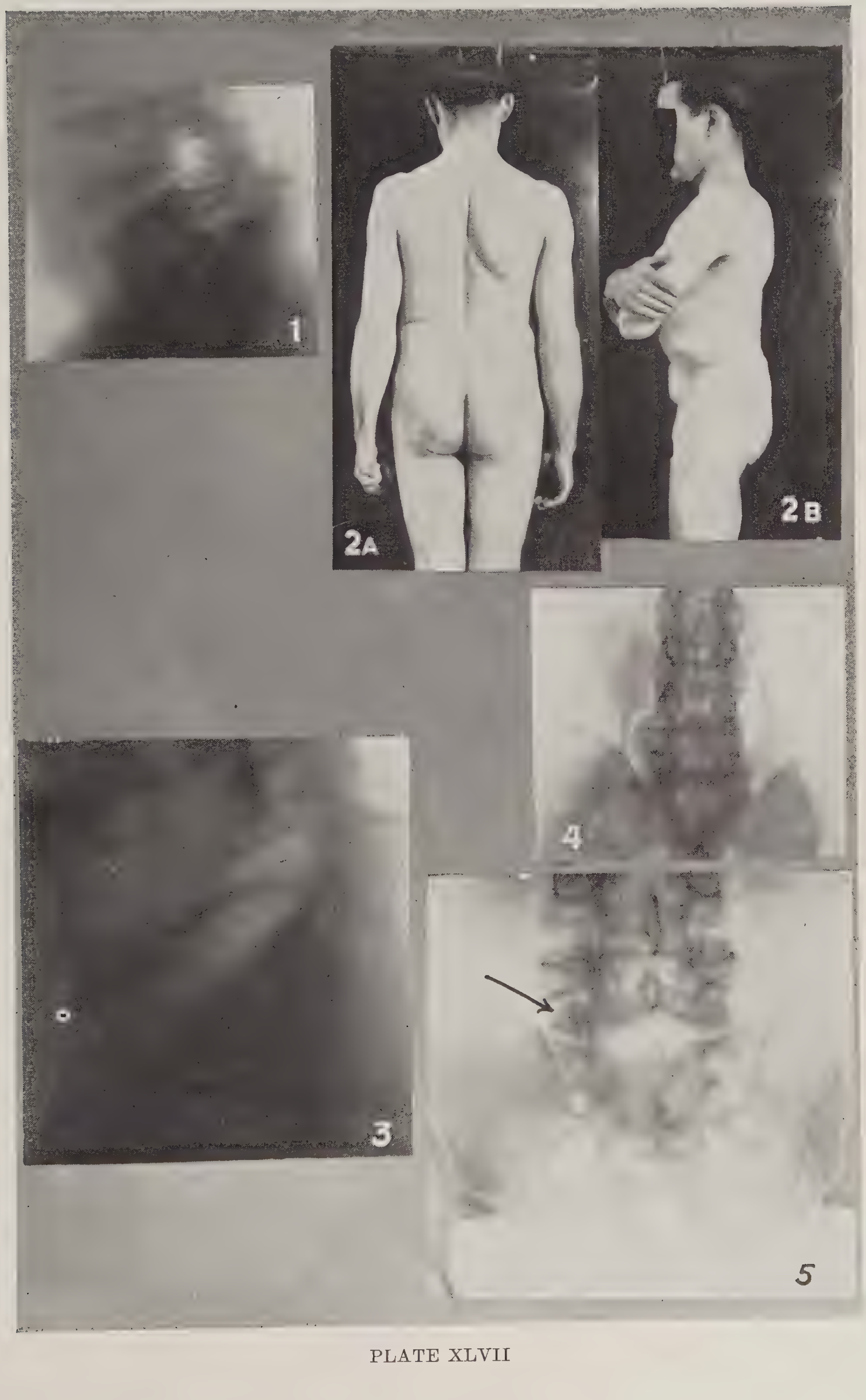


PLATE XLVII

IV. MECHANOGENESIS OF LOW BACK SPRAIN

Neither the sacrolumbar nor the sacroiliac junctions can be considered as thoroughly stable structures, as they depend intimately for support and stability upon the tone and integrity of the ligamentous apparatus. Under normal physiologic conditions relaxation of the ligamentous apparatus occurs only occasionally, for instance, during pregnancy or menstruation.

Pathologic conditions which facilitate such relaxations are trauma, general weakness or debility, or a more definitely established pathological process affecting the spine.

In the foregoing it was explained that there is either an extraordinary mechanical force applied to a normal spine (trauma), or an ordinary force applied to a pathologic or abnormal spine, or finally an extraordinary force applied to an abnormal spine, as the basic factor in the pathogenesis of the low back sprain.

1. External Strain Producing Force

Having considered, in the preliminary, the ranges of motion of the spine in different planes and the manner by which the ligamentous apparatus checks these motions, and finally the anatomical anomalies or pathologic changes which either restrict mobility or stability against external forces, it now remains to analyze the action of the external forces upon the spine themselves. The question arises whether the quality of the force and the circumstances under which it operates, mean anything for the production of the clinical symptoms.

The onset may be sudden or instantaneous as in acute trauma, or insidious such as in occupational strain.

The analysis of the physical force must come from the statements of the patient as revealed to us when taking his history. In cases of sudden onset one should go into great detail and if possible, have demonstrated the manner in which the injury was brought about, so that a conception may be gained of the strain-producing force, its direction and tendency, and also of the location at which it most likely became applied to the body.

A rotating twist of the body may be produced from above by the pitching of a ball or the swinging of a golf club; or the force may be imparted through the lower extremity to the pelvis as in the tackling during a football game, running, or the sudden throwing of the body to the side; or the force may be transmitted both from above through the spine and below through the lower extremities, to the sacrolumbar or sacroiliac articulations.

A fall from a height, the striking of a heavy load upon the shoulders, represent forcible forward flexion which is again transmitted through the body or lower extremities to the pelvis and is more likely to take effect at the lumbosacral junction or parts above. Upon diving from a height with the body extended, upon attempting to catch a ball overhead, upon slipping on the ice with a sudden violent jerk, upon riding in a rough riding car, or from the lurch of a riding horse, a forcible backward extension of the spine could be produced and a strain be caused in the sacrolumbar junction.

2. Attitudes and Postures

Besides the external violence other features must be taken into consideration; for instance, the attitudes and postures maintained by the spine at the moment when the injury is received, or an inherent predisposition due to habitual posture. Among attitudes or postures which play a rôle predisposing to sprain by sudden trauma there have already been mentioned the extreme lordosis, and the sitting with the lumbar curve reversed, as in lounging. These postures in themselves strain the sacrolumbar and sacroiliac articulations and if continued, result in weakness and relaxation of the ligamentous apparatus. In stout persons, either men or women, the drag of the abdominal organs causes lordosis which results in strains of the pelvic joints; this explains their frequency in persons of this anatomic build. A general lack of tone also greatly predisposes to this type of strain; since the bones are held in place in the sacroiliac junction almost entirely by ligaments, their relaxation under the influence of general debilitating conditions must lead to a great degree of instability of the spine.

V. SYMPTOMATOLOGY OF LOW BACK SPRAIN

1. General Symptomatology

The clinical recognition of an existing sprain in the sacrolumbar or sacroiliac junctions again rests upon four cardinal points: (1) there is a definite and circumscribed point of tenderness to pressure; (2) there is spontaneous pain in the joints on motion in direction in which sprain is primarily produced, that is, if further strain or stress is placed upon the injured ligament; this motion produces positions of aggravation; (3) when such position or attitudes are reversed, that is, if positions are assumed opposite to those in which sprain was primarily produced, a relief from painful symptoms ensues; this position is called the position of relief; (4) acute sprains yield to immobilization of the joint in such a position as will relax the strained ligament.

To these four points which govern strains in general, certain qualifications, however, must be made for the sprains originating in the lower back.

(1) The point of tenderness upon pressure loses its distinctness as the strain passes from the acute to the chronic stage.

(2) The strain relieving posture which is converse to the one in which the sprain was primarily produced, may change also as the acute tenderness of the sprained ligament subsides and other painful complications of the sprain come into the foreground. Such secondary painful complications on their part may demand a position opposite to the one originally adapted for the relief of the ligamentous strain. This point is well illustrated in certain cases of

sacroiliac sprain. Here, the position of relief is the inclination of the body to the opposite side. When, however, a secondary symptom, for instance, tenderness of the sacrolumbar plexus appears, then the position of relief is often changed from a tilt to the opposite, to a tilt to the same side.

(3) The fact that low back sprain is often not relieved by immobilizing measures does not disprove the assertion that these sprains, too, respond to rest. The fault lies in the methods of immobilization which are usually incomplete and inefficient.

(4) The analysis of low back pain is based upon the conception that the primary lesion is a sprain, that is, an injury to the ligamentous apparatus; but it is not thereby to be inferred that ligamentous sprain constitutes all the pathology of the low back disorders. On the contrary, a good deal of attention must be given to the musculature and especially to the nervous derangement which either accompanies or follows sprains.

2. Special Symptoms

a. Local Pressure Pain.—

(1) *In Sacroïliac Joint.*—Here, pressure pain is found just median to the posterior inferior spine of the os ilei. It denotes a tender sacroiliac joint which, at this point, lies superficially enough to be reached by the palpating finger (Plate XLVIII, 1, c). Strain of the posterior sacroiliac ligamentous apparatus usually yields a pressure point at the lateral edge of the sacrum, from the posterior superior spine downward (Plate XLVIII, 1, b).

(2) *The Sacrolumbar Region.*—When the tenderness is localized in the midline it denotes involvement of the interspinous ligaments, if more laterally to the vertebral bodies it denotes strain of the iliolumbar ligament (Plate XLVIII, 1, a, d). Sprain of the ligamentum sacrotuberosum and sacrospinosum also occurs and it gives pressure tenderness extending from the lateral borders of the sacrum to the spine or tuber ossis ischii (Plate XLVIII, 1, e).

In extreme degrees of relaxation the pain is considerable and the helpless patient is forced to assume recumbency. The slightest motion, such as raising the knees or moving the feet, is associated with definite movement of the pelvic joints causing local pain and discomfort. The local pain is usually worse after sleeping, when the spine and muscles have become relaxed and the joint strain is, therefore, increased in the sacroiliac junction (Goldthwaite[39]).

All three of the pelvic articulations may show the described pressure pain concomitantly. In some cases sitting is impossible unless the weight of the body is supported. This is done by placing the elbows upon the knees or by holding on to the seat of the chair.

An interesting study of an anterior location of pressure pain was made by Carnett;[18] he calls attention to a midline tenderness limited to the area of the lumbar vertebral bodies. It can be elicited by careful examination. The patient manifests tenderness as soon as the lateral surfaces of the bodies of the vertebrae are palpated through the abdominal wall. Such tenderness is usually due to the chronic strain of the vertebral joints and occasionally to localized or diffused arthritis. It is more marked the greater the lordosis and is especially so in the increased postural stress existing in the round hollow back. According to Carnett this anterior midline tenderness is most easily demonstrable two inches above the umbilicus where the convexity of the lumbar lordosis carries the vertebral bodies closest to the anterior abdominal wall. Tenderness of the superior portion of the sacroiliac joint can also be established by anterior palpation. This is located in a line parallel with and about one inch away from the lumbar vertebrae.

b. Spontaneous Pain in Sacrolumbar and Sacroiliac Articulations.—In certain positions spontaneous pain becomes aggravated. This occurs usually upon lying upon the back when the lumbar spine becomes flattened and necessarily strains also the sacroiliac ligament. It happens only, however, when the muscles are relaxed, as during sleep, and it explains why these patients often awake with severe suffering. This pain is usually relieved by stretching or some change of position in which the lumbar spine and the sacrum are drawn up (Goldthwaite). Lounging, sitting with the lumbar spine thrown back, prolonged walking or standing likewise brings on or aggravates spontaneous pain in sacroiliac or sacrolumbar derangement.

c. The Radiating Pain.—Radiating pain is a frequent symptom both in sacrolumbar and especially in sacroiliac strain. The proximity of the nerve roots forming the sacrolumbar plexus as well as that of the sympathetic nerve plexus, to the sacrolumbar and sacroiliac articulations, explains this frequency (Plate XLVIII, 2).

Radiating pain down the posterior aspect of the thigh, calf or sole, following the distribution of the sciatic nerve was found by Wentworth in 36 per cent of cases of sacroiliac strain, and in 43 per cent of cases of sacroiliac subluxation. On the other hand, only in 15 per cent of the sacrolumbar sprains and in about 20 per cent of the static back strain, this same type of radiation was observed (Plate XLVIII, 2).

Among his series of over three hundred cases the author[92] found radiation along the sciatic nerve in 67 per cent of all cases of sacroiliac sprain examined for radiation, but only in 28 per cent of the cases of sacrolumbar sprain. (See Table III.)

Radiating pain along the sciatic nerve is, therefore, much more frequent in sacroiliac than it is in sacrolumbar derangement.

It is assumed that this referred pain is due to pressure or pull upon the nerves of the sacral region. The upper part of the lumbosacral plexus passes directly over the upper part of the sacroiliac articulation, so that a slight displacement, or adhesions resulting from sprain, may easily cause pressure or pull upon these cords. The pain may be referred to any part below the seat of the trouble: to the thighs, the hips, down the back of the leg following sciatic distribution, and it is usually more pronounced on one side than on the other. It is supposed that this nerve involvement is based upon

PLATE XLVIII

Fig. 1.—Pressure points.
- (A) Iliolumbar ligament.
- (B) Sacroiliac ligamentous apparatus.
- (C) Sacroiliac joint (posterior end).
- (D) Sacrolumbar.
- (E) Ligamentum sacrospinosum.

Fig. 2.—Diagram of radiation of pain distribution among 375 cases of low back strain; sacroiliac group (author's series):
Dotted—gluteal region radiation. (5.5%)
Shaded—sciatic radiation. (67.0%)
Striped—upper lumbar plexus. (6.7%)
No radiation—(20.8%).

Fig. 3.—Asymmetrical position.
- (A) Homolateral, and
- (B) Heterolateral tilt.

Fig. 4.—Forward flexion in standing.
- (A) Sacrolumbar.
- (B) Sacroiliac.

Fig. 5.—Forward flexion sitting.
- (A) Sacrolumbar.
- (B) Sacroiliac.

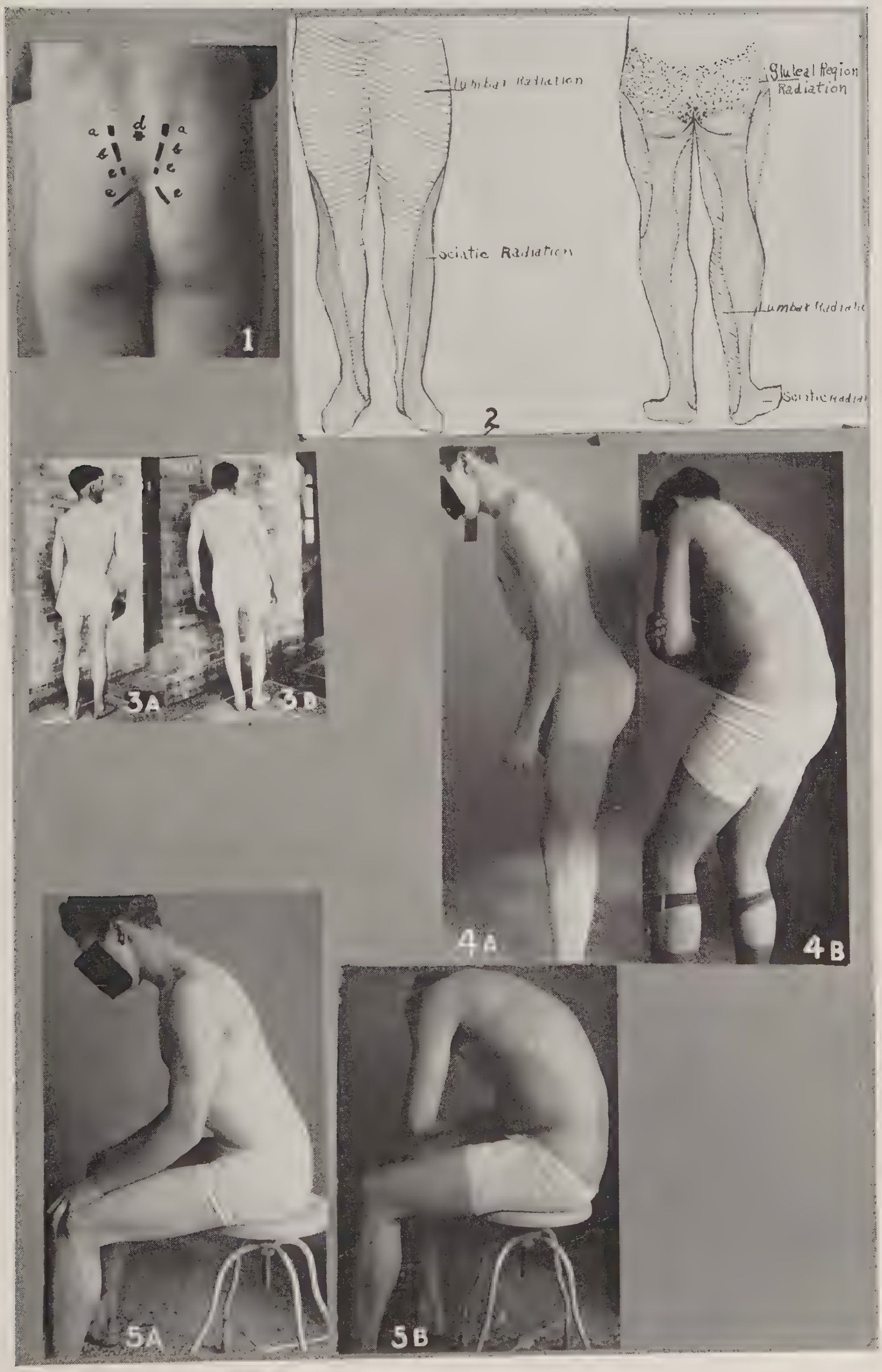


PLATE XLVIII

mechanical irritation or adhesions of the nerve trunk, forming at, or distally from, the point where they leave the spinal canal through the intervertebral foramina. The proximity of the injured ligaments which may easily involve the nerves in reactive hyperemia, hemorrhage, or scar formation, gives ground to this assumption.

Concerning the anatomic relations between plexus and 4th transverse process, one sees that the 4th lumbar root passes immediately in front of it, while the 5th root runs closely in front of the 5th lumbar transverse process. It is believed that even a slight change in the position of these transverse processes will result in pressure upon these roots and the rotatory deformity observed in some of the cases is considered as the cause of the radiating pain. On this assumption Baumann[7, 8] advocates the removal of the transverse process, reporting nineteen cases with fourteen cures. In the majority of cases, it seems more likely that the rotatory deformity of the spine is secondary to the nerve involvement and not the cause of it.

To this must be added that anomalous postures and reflex muscle contractures also exert a certain degree of pressure or tension upon the nerves. The sciatic nerve before leaving the greater sciatic notch runs along the anterior surface of the pyriform muscle, at the lower border of which it leaves the pelvis to reach the posterior side of the thigh, and it may be assumed that contracture of this muscle exerts pressure upon the nerves.

Concerning the relation of the intervertebral foramina to the nerve roots, a theory is gaining ground that a direct pressure upon the nerve is exerted by adhesions or inflammatory reaction at the point of their exit from the vertebral foramina. Putti[98] believes that sciatic pain is symptomatic of intervertebral arthritis, a neuralgia caused by pathologic conditions of the intervertebral foramina, and especially of the intervertebral articulations. He and Sicard[88, 89] apply to this condition the name ''neurodocitis'' (*neuron,* nerve; *dekon,* to contain). Danforth and Wilson[24] explain the radiation symptoms as a sign of incongruity between the lumen of the intervertebral foramen and the caliber of the nerve passing through it. It is, however, not generally conceded that such an incongruity exists, except in cases in which the opening of the intervertebral foramina is pathologically narrowed, as might occur in arthritis with lipping and spur formation.

c. Types of Radiation (Plate XLVIII, 2; Table III).—Clinically we might divide radiation in the following types:

(1) *Radiation Along the Course of the Superior Gluteal Nerve.*—This nerve comes from the 4th and 5th lumbar and 1st sacral and supplies partly the sacroiliac joint. It is likewise the nerve for the gluteus minimus and medius muscles. This type of pain is found in 7 per cent of the sacroiliac strains, and in 2 per cent of the sacrolumbar strains (Wentworth).

The writer finds gluteal radiation of pain in 5.5 per cent of the cases of sacroiliac strain, in 2 per cent of sacrolumbar strains and in 10 per cent of combined sacroiliac and sacrolumbar strains.

(2) *Sciatic Radiation.*—The most common distribution is along the sciatic nerve, which is formed by the 4th and 5th lumbar and upper three sacral roots. Sometimes this distribution is confined to the sacral roots alone and it then extends over the back of the thigh and the lateral sides of the leg and foot. Sometimes the two lower lumbar roots alone are involved and then the radiation includes the median side of the leg and foot. This distribution of radiating pain was found in 67 per cent of the sacroiliac, in 24 per cent of the sacrolumbar and in 42 per cent of the combined strains in the writer's series of three hundred and seventy-five cases (see Table III).

(3) *Bertolotti's Syndrome.*—This is a complex of sensory nerve symptoms associated with sacralization of the 5th lumbar vertebra. It was first mentioned by Patterson in a monograph which appeared in 1893, but attention was focused upon it only after the investigations of Bertolotti[11] in 1917. It is believed that the strain upon the nerve roots incident to the sacralization of the 5th lumbar vertebra produces the neuralgic disturbances.

Aside from Bertolotti, Rossi,[80, 81] Schiassi,[83] and other Italian proponents of this theory that sacralization, or pseudosacralization has something to do with lumbosacral sciatic neuralgia, many French authors (Nove-Josserand,[67] Randu, Feil,[32] Ledoux[56]) share this belief in a connection between sacralization and gluteal or sciatic neuralgia. This syndrome which consists in pain along the distribution of the lumbosacral plexus, especially of the 4th and 5th lumbar roots seems to make its appearance at adolescence or at middle age. The long latency of a condition caused by congenital anomalies seems strange, but it is being explained by Bertolotti by the fact that the final development of the skeleton especially of the apophyses of the transverse processes in adult life causes the hitherto latent syndrome to become manifest. The tips of the transverse processes do not become entirely ossified and fused with the body until adult age or late in the third decade. Nevertheless, some superinducing factor seems to be necessary to bring out the syndrome. It was observed by Leri[57] that sacralization even if complete, is rarely alone the cause of pain, and its discovery in the x-ray picture is not sufficient grounds to explain deformity or painful disability of the back. The significance of sacralization or pseudosacralization with respect to nervous symptoms is summarized by Denucé[25, 26, 27] as follows: the sacralization is either a true one in the anatomic sense, showing complete articular contact by fusion of the 5th lumbar with the sacrum or os ilei, or a pseudosacralization which might be the result of traumatic affections or calcifications of ligaments, osteophytes, of periostitis, fracture or displacement.

In the first case the appearance of the syndrome of Bertolotti may be construed as a true growth phenomenon coincident with the ossification of the tips of the transverse processes. In the latter instance the sacralization is merely incidental and the supervening pathologic condition is the basis of the neuralgic symptom-complex.

As for the frequency of sacralization under normal conditions, extensive anatomic and x-ray studies made by A. A. Small on cadavers as well as on living persons, showed it to be found in 3.8 per cent. It is found more frequently bilaterally than unilaterally (Lupo[61]). In the first and second decade it is not accompanied by nervous symptoms and disturbances are exceptional. On the other hand, as already mentioned, it is often associated with congenital malformations of other nature, of the spine as well as of the extremities and the pelvis. That sacralization is so frequently found in infancy is easily explained by the assimilation process through which the pelvis ascends higher in its ontogenetic development. It is more difficult to explain asymmetrical sacralization. This is found, according to Lupo, in 20 per cent of the cases, an observation somewhat at variance with other observers (Goldthwaite,[37, 38] Denucé,[25, 26, 27] Calvé, and others). The sacral segments maintain their independence up to the 15th year, after which time fusion of the sacral segments begins, but this also is not complete until the twenty-fifth or thirtieth year. This slow progress of the osteogenetic development of the lumbar section, explains logically the slow occurrence of morbid symptoms arising from sacralization of the 5th lumbar vertebra.

All in all the proportion of patients suffering from sciatica and having also an anomaly of the 5th lumbar vertebra is too great to be considered simply a matter of chance coincidence, and it is the opinion of most authors that such an anomaly, when marked, favors the development of these painful symptoms (Zimmern, Lauret and Weill[103]). The comparative frequency of sacralization without symptoms is also observed by Albanese,[2] who is convinced that its presence does not, in itself, mean clinical symptoms. While the presence of Bertolotti's syndrome is always associated with variations in the form of the 5th lumbar, the opposite, therefore, is by no means true. The appraisal of the true significance of sacralization for the production of nerve symptoms is, indeed, extremely difficult. Pain in lumbar and sacral regions is so frequent and is associated with so many other conditions that it is not surprising when many authors (Beck, Schüller[85]) do not make anything of this factor as a producer of clinical symptoms.

In spite of all these arguments to the contrary, however, the weight of opinion points to the fact that sacralization is still an important contributory cause in the production of low back pain.

(4) *Lumbar Radiation (Plate XLVIII, 2; Table III).*—This manifests itself by pain radiating into the groin and into the outer side of the thigh. It is much less frequent than the sciatic radiation and is found preponderatingly in the sacrolumbar strain. Only in 6 per cent of the sacroiliac strains, in 10 per cent of the sacrolumbar sprains, and in 2 per cent of the static sprains is this type of radiation encountered (Herndon).

In the writer's series upper lumbar radiation was found in 6.7 per cent of the sacroiliac sprains, and in 5 per cent of the sacrolumbar and combined sprains against 10 per cent given by Herndon.

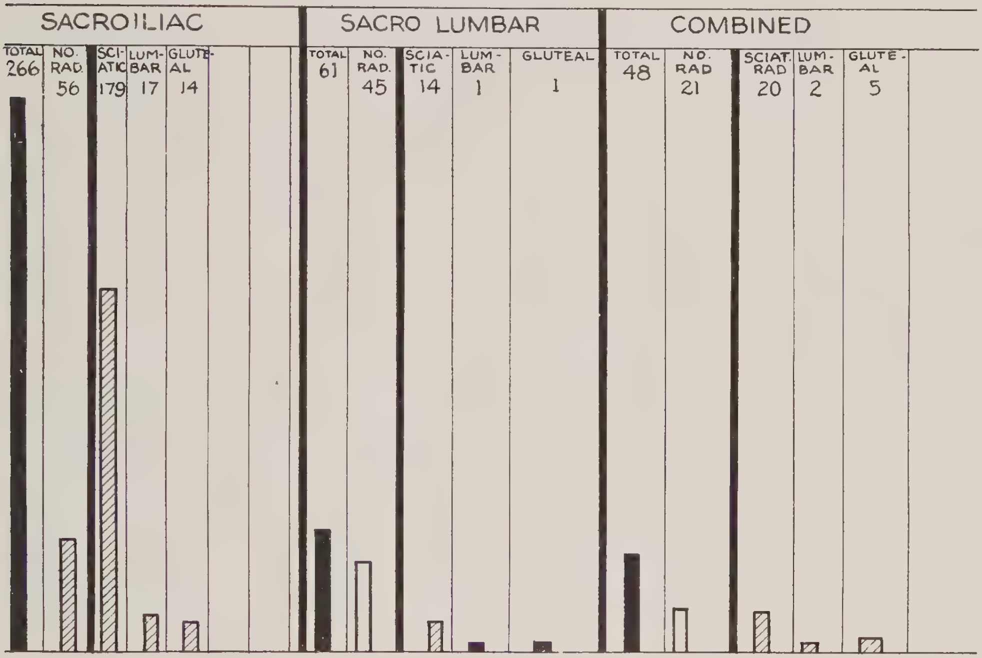
Summary.—In general, radiating pain is found in much higher frequency and with much greater regularity in the sacroiliac sprain than in the sacrolumbar; and, in the former, the sciatic distribution is decidedly predominating. For the sacrolumbar sprains a slightly higher frequency of lumbar radiation is observed by some, but it is still very infrequent as compared with the incidence of sciatic radiation in sacroiliac derangement.

d. Posture in Low Back Sprain.—The abnormal posture which the patient presents at examination is the automatically assumed position of relief. This position may be symmetrical or asymmetrical.

(1) *Symmetrical Position.*—In the sacrolumbar sprain the position of relief is hyperextension with accentuation of the lumbar lordosis due to the contracture of the long muscles of the back. The center of gravity appears carefully shifted backward.

TABLE III

RADIATION *of* PAIN



In bilateral sacroiliac sprain the position of relief is the opposite, the patient stands in slight forward flexion and is unable to extend his spine. The upper end of the sacrum appears tilted backward and the superincumbent lumbar spine is flexed forward. The primary object of this position is to relax the tension of the psoas muscle, and, hence, to keep it from forcing the spine and sacrum into a lordotic position. The discomfort which appears at the slightest movement causes the patient to maintain this position of relief with the utmost rigidity. In severe cases the position is held so rigidly that standing or walking becomes extremely difficult.

(2) *Asymmetrical Position (Plate XLVIII, 3, a, b).*—It is seen in unilateral sprain of the sacroiliac joint. Here the position of relief is usually inclination of the body to the opposite side, that is, a contralateral tilt. This tilt is more often seen in recent cases than in older ones. In older cases the primary ligamentous sprain may have worn off and the secondary neuralgic symptoms come into the foreground. Then the position of relief is no longer dictated by the ligamentous sprain but by the involvement of the sacrolumbar plexus and especially of the sciatic nerve; the position of relief now becomes a tilt to the affected side or a homolateral tilt. In the sacroiliac sprains this tilt was noticed contralateral in 25 per cent and homolateral in 8 per cent in the author's series; and in 8 per cent contralateral and 8 per cent homolateral in the combined sacroiliac and sacrolumbar sprains.

e. Mobility.—The mobility of the spine in sacrolumbar and sacroiliac sprains. In order to make apparent the degree and direction in which motion of the spine is restricted the patient is made to go through the movement of the spine in different planes of the body. For this examination the excellent technique of Smith-Peterson[419] is especially to be recommended. The routine examination for mobility of the lower back is carried out in the standing, in the sitting, and in the lying down positions.

(1) *Restriction of Motion in Standing.*

(a) Forward Flexion.

(i) Lumbosacral Sprain. The patient when told to bend forward will do so with body held rigid to avoid all forward flexion in the lumbar spine. This movement, therefore, will be carried out largely in the hip joint, and it will proceed as long as it can, by movement of the pelvis against the femur until it is checked by the tension of the hamstring muscles (Plate XLVIII, 4a).

(ii) In sprain of the sacroiliac articulation, however, the body is held in forward flexion and continues to flex forward in the lumbar spine until the limit is reached and further flexion must be carried out in the hip joint, as in the case of sacrolumbar strain. Because of the tenderness of the sacroiliac junction, however, the tension of the hamstrings developing during forward flexion is not tolerated and the patient, therefore, relieves these muscles by bending the knees. In general the patients are unable to do any degree of forward bending without, at the same time, flexing knees and hips (Plate XLVIII, 4b).

(b) The Hyperextension of the Trunk in Standing.

(i) In sacrolumbar sprain extension of the trunk in the lumbar spine is limited because it increases the stress upon this articulation. Whatever extension is possible must be carried out mainly in the hip joint. The patient by flexing the knee places the center of gravity farther backward so as to allow an additional backward throwing of the body.

(ii) In the sacroiliac sprain, however, extension is possible only in so far as it is not transmitted to the sacrum. It is, therefore, also very limited and the patient resorts to the same maneuver in flexing the hip and knee and throwing the whole trunk backward.

(c) The Rotation Movement in Standing. Rotation has very little effect upon the sacrolumbar involvement, since it is normally very little represented in the lumbar spine.

In sacroiliac sprain, however, rotation is transmitted to the pelvis, and next taken up by the hip joint. When the range of rotatory motion in the hip joint is exhausted, then the leverage becomes effective upon the sacroiliac junction and causes pain. For this reason rotation is also guarded and the trunk rotates as a whole in the hip joint. Normally there is no independent mobility in the sacroiliac articulation, but relaxation in pathologic cases may be so marked that the pelvic bone can be moved about freely (Goldthwaite[38] and Osgood).

(2) *Mobility of the Spine in the Sitting Position.*—The patient is next told to sit down, and motion is tested in different planes.

(a) Flexion. In the sacrolumbar sprain the patient bends forward stiffly in the hip joint without executing any motion in the lumbar section, the latter being immobilized by muscle contracture (Plate XLVIII, 5a).

In the sacroiliac sprain, however, the patient is able to flex forward in the lumbar spine. This forward flexion goes much farther than it did in standing because with the knees flexed there is no further leverage exerted upon the hamstrings and a considerable degree of flexion can now be carried out without strain upon the sacroiliac articulation (Plate XLVIII, 5b).

(b) Extension.—Backward extension of the trunk with the patient in sitting position is somewhat limited in lumbosacral sprain similarly as it is in standing. In the sacroiliac sprain, backward extension in sitting position is especially limited by the forward flexed posture of the trunk and the tenderness and pain caused by sacrospinalis and gluteal contraction.

(c) Rotation in Sitting Position.—For reasons mentioned there is usually no great impediment to rotation in sacrolumbar sprain. In the sacroiliac sprain, however, the patient is more sensitive to rotation while sitting than he is in standing, since in the sitting position the pelvis is fixed, while in the standing position the rotation of the body is taken up by movement in the hip joint.

(3) *Examination in the Lying-down Position.*—The patient is next told to lie down and the movements are carried out by moving the pelvis and the lower extremities against the trunk.

(a) Flexion.—In the sacrolumbar sprain the patient is told to flex the hips and knees, and to draw the knees up. One notices that the lordosis in the lumbar spine caused by the contraction of the long muscles of the back does not change.

In sacroiliac sprain, however, when the hips are flexed and the knees are drawn up, then the lumbar lordosis becomes effaced, as it does normally, because the lumbar spine not being affected easily accepts the forward flexed position, finding no obstacle to this movement.

(b) Extension.—Extension and lateral bending differs little in range of motion from that found in the sitting and lying positions.

f. Passive Mobility.—Examination for passive mobility brings out special signs which are of great value in the diagnosis and allocation of low back pain.

(1) *Forcible Compression of the Iliac Crest.* The patient is turned to the side and the iliac crests are compressed against each other by the incumbent weight of the examiner; this often elicits pain in a sprained sacroiliac joint, but it usually has no effect upon the sacrolumbar articulation.

(2) *Laguere's Sign.*—This sign is usually used in testing the condition of the hip joint. The thigh is carried into abduction, flexion and external rotation, and the knee is pressed down strongly against the table. As a result, the femoral head bears against the anterior portion of the capsule, and pain is produced if there is effusion or irritation of the joint. This maneuver also transmits strain to the sacroiliac articulation on the same side, and in case of affection of this junction, pain is produced. There is usually no effect upon the sacrolumbar articulation (Plate XLIX, 1).

(3) *The Straight Leg-Raising Sign.*—Straight leg-raising elicits pain where there is sciatic radiation whether in the sacroiliac or in the sacrolumbar derangement. As a contralateral sign, it is of great importance to detect a highly increased sensitiveness of the sciatic nerve. If the leg on one side is elevated with the knee extended, the gluteals on the other side must contract in order to force the heel of the resting leg firmly down against the bed. If the sciatic nerve is very sensitive, or if there is a very tender sacroiliac joint on the resting side, this gluteal contraction causes pain contralaterally to the elevated leg (Throckmorton's sign).

(4) *Goldthwaite's Sign.*—The thigh on the affected side is flexed strongly and the knee is extended; this produces tension of the hamstring muscles, eliciting pain in the affected sacroiliac articulation (Plate XLIX, 2).

(5) *Gaenslen's*[36] *Sign.*—Thighs and knees of the affected leg are strongly flexed and the limb is pressed against the chest; upon hyperextension of the other hip, pain appears in the affected sacroiliac articulation (Plate XLIX, 3).

(6) *Hypermobility of the Affected Joints.*—Hypermobility may be demonstrated by forced hyperextension of the thigh which causes the os ilei on this side to move away and forward from the sacrum. It can also be produced by pressing the sacrum with one hand and gripping the os ilei with the other, thus testing for motion between the two bones.

Hypermobility of the spine is an unusual symptom in simple sprain; it does occur, very exceptionally, in severe traumatism of the pelvis with separation and diastasis of the pelvic bones.

g. Sciatic Scoliosis (Plate XLVIII, 3a, b).—According to Denucé[26] it was Charcot,[20] who in 1886, first noted a relation between sciatic neuralgia and the inclination of the trunk, though Albert[3] of Vienna, Nicoladoni,[66] and also Gussenbauer[45] (1878) claim priority over Charcot's discovery.

1. *Classification.*—There are many theories concerning the pathogenesis of the sciatic scoliosis. They may be classified under four headings: (1) a reflex

muscle contracture (Brissaud[15] and Lorenz[60]); (2) paralysis or paresis of the musculature of the trunk; (3) shifting of the body weight; and (4) maximum relaxation of the nerve trunk, or of its different roots to avoid neuralgic symptoms caused by certain movements.

According to Sicard[88, 89] a distinction is to be made between total sciatica if the entire nerve is involved; the high sciatica with localization from the foramen to the conjugation of the plexus; the middle sciatica localized from the intertrochanteric fossa to the greater sciatic notch, and finally the low sciatica located from the thigh and popliteal space downward. All these have a different effect upon site and form of scoliosis. Sicard believes that the homolateral scoliosis accompanies a middle localization, that is, tenderness from between the trochanter and tuber os ischii to the greater sciatic notch, because this type of scoliosis relaxes both the sciatic and the sacral plexus. On the other hand, a contralateral scoliosis accompanies the involvement of the roots of the plexus from the foramina to the junction because this form of scoliosis opens the foramina while it relaxes the sacroiliac articulations.

2. *Symptoms.*—The trunk as a rule inclines to the opposite side, thereby shifting the body weight away from the affected limb (Plate XLVIII, 3, b). This inclination of the trunk produces a lumbar curve which points its convexity to the affected side. According to Charcot[20] and Babinski,[4] this deviation is caused by active muscle action on the part of the muscles of the sound side. Nicoladoni[66] believes that the neuralgic sciatic is the seat of inflammatory swelling extending into the vertebral canal and that the patient assumes a scoliotic position in order to give more room to the corresponding half of the cauda equina.

In contrast to the usual contralateral tilt, Albert and Lorenz[60] as well as Brissaud[15] first described a homolateral inclination to the affected side with the convexity of the lumbar spine pointing to the sound side (Plate XLVIII, 3a). That these are true cases of scoliosis is extremely doubtful. Denucé maintains that it is only an abnormal attitude which the patient assumes to relieve the affected side from weight bearing, and that this attitude is temporary only. If a true scoliosis is found together with sciatica, one must assume that the neuralgia is secondary and that both sciatica and scoliosis are based upon a common cause.

The explanation of the sciatic scoliosis as resulting from the effort to shift the body weight from the affected side to the sound side (Albert) is further elaborated by the observations of Ehret[29] and Bähr,[5] who observed in connection with the lateral deviation also an abnormal inclination of the pelvis supposedly due to the efforts of the patient to relieve the nerves from pressure. According to the anatomic studies of Ehret both the sciatic and the femoral nerves have their straightest course when the thigh is held in slight flexion, abduction and outward rotation, a position frequently seen in cases of sciatica and sciatic scoliosis.

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Fig. 1.—Laguere's sign: forcing leg in flexion, abduction and Outward rotation elicits pain in sacroiliac joint.

Fig. 2.—Goldthwaite's sign: tension of hamstrings elicits pain in sacroiliac joint.

Fig. 3.—Gaenslen's sign: Hyperextension of hip elicits pain by rotation transmitted to affected sacroiliac. Immobilized by flexion of other thigh and knee.

Fig. 4.—Recumbency arrangement for sacrolumbar strain. (Note boards under mattress and cushion under lumbar spine.)

Fig. 5.—Strapping for sacroiliac strain.

Fig. 6.—Strapping for sacrolumbar strain.
(Note straps running crosswise from below buttocks to opposite shoulder.)

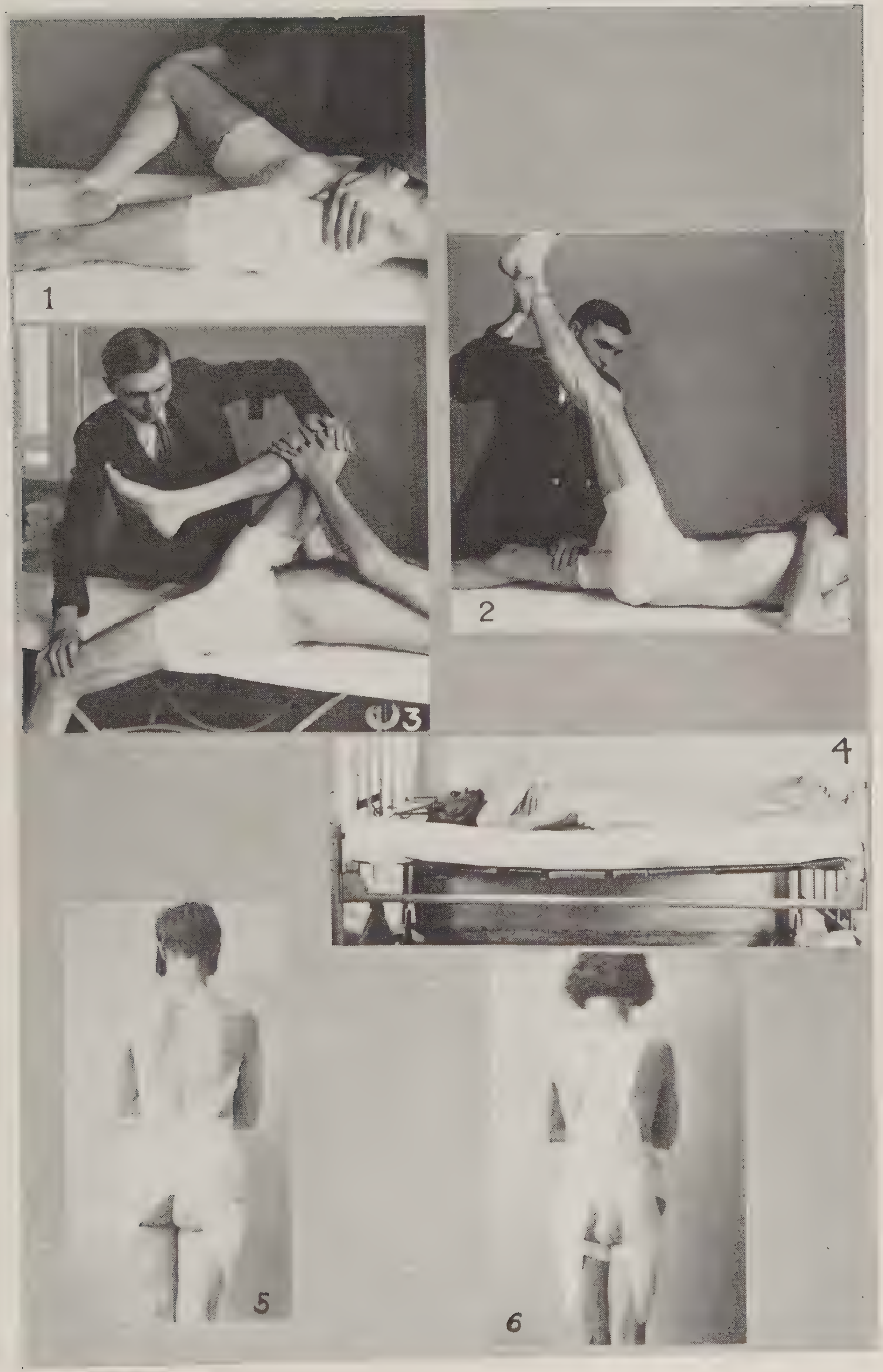

PLATE XLIX

Since (1912) Goldthwaite[38] and Osgood, on the basis of careful anatomic studies, demonstrated that sacroiliac articulations are true joints, subject to all lesions of joints, the question of the connection between scoliosis and sacroiliac affection has assumed new significance. If the sacrum is at all displaced, the lumbar curve becomes obliterated or even reversed, and if one side is more involved than the other a marked lateral deviation of the body may be present. This primary deviation is *always* away from the side of the affected joint.

It was Charcot's opinion that the sciatic scoliosis is due to reflex contracture caused by the effect of the sensory nerves which supply the muscles of the pelvis. Contracture of these muscles is painful and therefore attitudes are assumed in which these muscles remain relaxed.

Others again (Schüdel[84]), see in this posture an expression of the insufficiency of the erector spinae mass and of the quadratus lumborum muscle which allow the trunk to become inclined to the other side. It has been pointed out that anastomoses exist between the posterior rami of the 1st to the 4th sacral nerves and a posterior sacral plexus from which the cutaneous nerves for the region of gluteal maximus and sacrococcygeal region arise, some of these sending rami to the sacrolumbaris muscle (Hyrtle). On these grounds the spread of the sciatic neuralgia to the extensors of the spine is explained, causing the postural anomaly of the trunk, even though there is no direct involvement of the upper roots of the lumbar plexus.

In sciatic scoliosis we find a distinct pressure point, a point of tenderness at the exit of the sciatic nerve from the pelvis, and similar ones over the superior and inferior gluteal nerves (Schüdel[84]). The pelvis on the affected side appears elevated and carried backward, the trunk is tilted to the opposite side and somewhat forward, so that a kyphoscoliosis results. In increased forward flexion this tilt to the unaffected side may become effaced. The cases which show forward flexion as well as side bending are especially obstinate.

The scoliosis itself consists of a lower lumbo-dorsal and a compensatory upper curve. The quadratus lumborum acts as a check to the lateral bending of the body, the leg on the affected side appears flexed in hip and knee. All the muscles involved, namely, the erector spinae, the quadratus lumborum, the abductors and outward rotators of the hip, have in common that they are supplied by nerves which come almost at right angles from the main trunk and keep a very short course from the foramina of the sacrum and the lumbar spine to their point of destination. Since these very short nerves have no slack, they are exposed to mechanical forces, and constant pulling or jarring of the short muscle branches may easily produce neuralgic symptoms. Bucholz[16] analyzing seven hundred and sixty-one cases of sacroiliac strain in the Massachusetts General Hospital found among those one hundred and seventy-four cases with lateral deviation of the spine, or 22.7 per cent; and this is still a rather low percentage. The proportion of the homolateral tilt to that of the opposite side he found to be as six to thirty.

Bucholz finds sciatic scoliosis a rather frequent affection concerning mostly the ages between thirty and forty, while it is never seen below puberty nor above sixty. Goldthwaite, Painter, and Osgood[40] and many other observers (Hatch,[48] Ogilvy,[70] Taylor[93]) confirm these observations both in regard to frequency in general and to the preponderance of the contralateral tilt in sacroiliac sprain.

Lateral deviation, therefore, should suggest a unilaterally displaced sacrum or relaxation of the sacroiliac articulation, similarly as decrease of the lumbar lordosis denotes a bilaterally relaxed articulation (Goldthwaite, Nutter[68]).

h. Alternating Sciatic Scoliosis.—Remak[79] was the first to observe a change from the heterolateral to the homolateral type in some cases of sciatic scoliosis. In the ordinary type the deviation, whether homolateral, or, more often, heterolateral, remains constant. There are, however, exceptional cases in which a voluntary or involuntary change in posture of the body is observed; this is called the alternating sciatic scoliosis. Up to 1925 only twelve such cases were reported in the literature (Calissano[17]).

Many explanations of this phenomenon have been offered. It is believed that the homolateral tilt occurs when the first three lumbar roots are involved, while the hetero- or the contralateral form occurs with the involvement of the 4th lumbar; and that in involvement of the 5th lumbar root there is no lateral deviation (Thoele[94]). In other words, when sciatic symptoms proper prevail, contralateral tilt of the body develops, and with it relief of body weight from the affected limb; while, if the lumbar symptoms prevail, then a homolateral scoliosis develops which affords greater relaxation of the muscles innervated by the lumbar plexus. Now, if both portions of the plexus are involved, the patient voluntarily alternates the position as he seems in need of relieving the tension in one or the other portions of the plexus. He never maintains the straight position because no relief is given in this position to any portion of the plexus.

The cases of involuntary alternating scoliosis show the clinical picture of involvement of the nerves of the lumbar region. Voluntary alternation is noted only after the acute symptoms have subsided and the trouble has been in existence for some time (Blencke[14]). The involuntary type of the alternating scoliosis is the forerunner of the much less frequent voluntary alternation. Ehret[29] believes that by exercises and training an involuntary alternation can be made into a voluntary one. Combined with the lateral deviation, there is also the effacement of flattening of the lumbar lordosis and a forward flexion of the body, all of which contributes to the relaxation of the sensory nerves (Schulthess[86]).

i. Sacroiliac Subluxation.—Whether or not there exists a true subluxation of this joint is still a mooted question.

Subluxation in the sense in which we speak of it in other articulations does not occur, at least it is not demonstrable by the x-ray picture. There are cases, however, which show a demonstrable mobility of the joints. The best argument for the assumption of a subluxation is the relief of symptoms brought about in some cases by definite changes in the positions of these bones. No matter how skeptical one might be in the matter of subluxation one cannot ignore the number of patients who make positive statements that upon certain manipulations of the thigh or upon certain movements of the body, the pain in the sacroiliac junction suddenly becomes relieved after a noticeable click is heard or felt. The irregular conformation of the joints renders it possible if not probable, that such displacement may occur, however slight, produced by a misfit between the numerous elevations and indentations of the joint. More than this theoretical explanation, however, the actual experience is convincing. It seems that many surgeons of experience have, during manipulations, met with sudden relief of symptoms as they endeavor to rotate back the os ilei upon the sacrum in correcting the pathologic backward tilt of the sacrum against the os ilei (Baer). The writer encountered several cases in which the statement of the patient that he had found relief by a sudden click during manipulation of the thigh, was so definite and unequivocable that it could hardly be doubted. These subluxations appear as more severe lesions than the simple sacroiliac sprains. There is more pain and more aggravation by movements of the spine. They also produce a greater percentage of radiating pain and other sensory symptoms.

VI. DIFFERENTIAL DIAGNOSIS

The diagnosis of sacrolumbar or sacroiliac sprain is based upon pain in the joint, atrophy of the muscles, characteristic attitudes in walking or standing, limitation of motion, local tenderness, swelling, and the radiation of pain. There are some conditions which offer particular difficulties in differentiation.

1. Fractures

Here, the diagnosis depends almost entirely upon the x-ray picture. Fracture of the 5th lumbar transverse process may give symptoms of sacrolumbar or sacroiliac sprain. Abnormal thickness of the transverse process with deflection or irregularity is not always evidence of previous fractures, however. While the majority of these fractures occur by direct injury to the lumbar spine, there are cases in which sudden muscular movement may cause a tear fracture of the transverse process (Herndon[50]). (See also Chapter on Fracture Deformities of the Spine).

Fracture of the body of the 5th lumbar may be mistaken for sacrolumbar sprain. The most common type is the compression fracture resulting from indirect violence principally forced forward flexion, or by fall of a heavy load upon the back. It may produce symptoms which are very similar to the simple lumbar sprain, but such fractures are usually demonstrable in a good x-ray view.

2. Chronic Deforming Arthritis

Here differentiation becomes at times very difficult. The presence of definite arthritic changes in the x-ray picture is evidence of chronic arthritis, but it does not exclude a concomitant sacroiliac or sacrolumbar sprain. On the contrary, such a sprain very often develops in spines definitely predisposed to it by arthritic changes. O'Farrell[69] states that the greater portion of his series of low back sprain in the lumbosacral region showed superimposed intercurrent infections in the form of arthritic changes. The relief of the low back symptom which follows removal of foci, or resection of granulations from defective teeth (Lurie[62]) points to the arthritic nature of many of the cases. Here also belong obliterations of the sacroiliac articulations. Blaine[13] found among 1800 x-ray pictures of the lower spine in 18 or 1 per cent unusual changes in the sacroiliac joint. There was a decrease in the sharpness of the contours, later erosions, and in still later stages, decrease in the interarticular fissure between sacrum and os ilei, which eventually disappeared leading to total obliteration. Of great importance for the differential diagnosis is the distribution of arthritic changes over a greater section of the spine.

3. Neurosis

A combination of nervous symptoms may follow injury without reference to definite location, or any demonstrable anatomic lesion. The diagnosis of spinal neurosis should only be made by exclusion. The patients offering neurotic symptoms are not necessarily malingerers. Their statements of suffering and pain may be given in perfectly good faith. Determining signs are: general condition of the patient, anemia, general weakness, excitability, palpitation, tachycardia, excessive sweating or other vasomotor abnormalities, irritability, depression, fear, etc. It is usually in the nervous, dynamic patient whose digestive processes are feeble and capricious, in cases with an intestinal distention and an abnormal body balance, that this post-traumatic, psychoneurotic backache is found (Courtney[23]).

4. Exaggeration and Malingering

These cases offer a most difficult problem for the diagnostician. Here, the absence of visible evidence of trauma, the general mental attitude of the patient, and above all things the discrepancy between the symptoms complained of and the actual anatomic and clinical findings are of importance. Far from becoming a subterfuge for malingerers, as some are inclined to believe, the anatomic and mechanical analysis of the low back condition is very apt to unmask unjustified complaints and to aid in the detection of malingerers. The fact that there is little or no corollary to the subjective complaints, and that no objective demonstration of the condition can be made, is of significance. In cases of litigation the surgeon should be given opportunity to point out the discrepancy between subjective complaints and clinically demonstrable symptoms. The exaggerator is not really a malingerer; it is possible that he makes his unduly high valuation of subjective complaints in perfectly good faith. There are, however, certain features about the symptom-complex of low back strain which cannot be feigned: Unilateral muscular rigidity cannot be simulated since the voluntary rigidity is *always bilateral.* Diffused and ill-defined tenderness, areas of anesthesia of indefinite and unanatomic limits are suspicious. From the legal point of view detection of exaggeration and malingering is of great importance, and the responsibility which rests upon the surgeon should prompt him to make his examination most thorough and complete. In the large series reported by Herndon,[50] covering nine hundred cases, fully forty-five or 5 per cent were malingerers.

5. Organic Diseases of the Spine

Of the organic diseases tuberculosis and malignancy of the spine offer the greatest material for differentiation. Here a careful history, a painstaking examination, competent x-ray plates usually settle the problem.

VII. THE TREATMENT

The treatment is conservative (recumbent or ambulatory), or operative. The former is the method of choice; the latter covers a minority of selected cases. For practical purposes it is convenient to divide the cases as follows: acute cases without radiation of pain and without postural anomalies; acute cases with radiation of pain and usually with postural anomalies; chronic cases without radiation; chronic cases with radiation and postural anomalies.

1. Recumbent Treatment

Recumbent treatment is indicated in acute cases with marked local symptoms without complication; furthermore, in acute cases with distinct postural anomalies and in acute cases with radiation.

The patient is put to bed and is given a cathartic, preferably hot senna tea, and aspirin. He must be placed upon a nonsagging mattress, underlaid with boards placed crosswise over the springs. Upon this the patient is put with his knees and hips flexed and these are then gradually extended as the muscle spasm relaxes. In addition to this, in sacrolumbar strain the contracted lordotic spine is supported by pillows or folded sheets placed under the hollow of the back until the latter rests firmly upon them. Traction is then applied upon the pelvis and limbs until all muscle spasm has disappeared (Plate XLIX, 4).

If postural anomalies exist this traction is continued until the patient, at least in recumbency, assumes an entirely symmetrical position. This may take from a few days' to a few weeks' time.

If sciatic radiation exists, traction upon the affected limb is used by means of adhesive or moleskin straps. In resistant cases of sciatic radiation, however, further and more radical measures become necessary (see later in text).

The traction in recumbency may also be applied by means of elastic webbing trunks, and in extreme cases a plaster of Paris bed fitted to the back, sacrum, buttocks, and thigh is given as support. It must be realized that some sort of support for the back is necessary during recumbency as much as during the ambulatory treatment. The pain is often most severe at night and can only be relieved by supporting the back with pillows, and by using traction in the manner described.

2. The Ambulatory Treatment

a. The Primary Ambulatory Treatment.—Primary ambulatory treatment not preceded by recumbency is indicated in acute cases of moderate severity and in chronic cases without disalignment.

(1) *The Strapping.*—Strapping with adhesive or moleskin adhesive plaster is a temporary measure for immediate relief. When strapping for sacroiliac sprain care should be taken to hold the os ilei close together by running the straps from in front of the anterior iliac spine across the back to the other side (Plate XLIX, 5). In all cases of sacrolumbar sprain longitudinal straps running across the shoulders, over the back to below the buttocks on the other side should be applied (Plate XLIX, 6). It is best to apply these straps in this diagonal direction, starting from below the buttocks, lifting up the gluteal muscles and then running across the back to the shoulder of the other side. Such an arrangement is especially useful in cases of gluteal radiation. The strapping is more satisfactory if a pad of felt is put under it, so as to make pressure over the sacrum. All strapping, as well as all other forms of immobilization of the back, must be applied in positions of relief.

(2) *Belts.*—The sacroiliac retaining belt is indicated in milder acute cases, in subacute cases and in chronic cases without complications. The sacroiliac belt is to retain the alignment between os ilei and sacrum, and to give a certain support to the musculature. It is essential that pressure be brought about at the level between the anterior superior spines and the trochanters.

For sacrolumbar sprains the belt must reach much higher, well above the lower costal margin. Pads are also applied to fill the hollow of the back so that pressure can be exerted upon this portion of the spine with more efficiency. All belts should be made from measurements. In many cases relief of pain is obtained by woven elastic trunks fitted about the thigh and across the buttocks; these are laced and buckled so that pressure may be controlled (Plate L, 1).

(3) *Braces.*—A support which is most satisfactory is that of Osgood.[74] It consists of a sacral pad with a steel spring to the ends of which wide webbing belts are attached crossing in front. The sacral pad is strapped firmly against the upper half of the sacrum.

Fitted leather torsos are also effective although somewhat inconvenient in stout patients.

A spring steel back brace may also be applied with advantage. This is made in the form of the so-called spring back brace with webbing belts attached

PLATE L

Fig. 1.—Corset belt for sacroiliac and sacrolumbar strain.

Fig. 2.—Spring back brace applied.

Fig. 3.—Spring back braces (two different types).

Fig. 4.—Result of sacrolumbar fusion (Albee's method) for severe sacrolumbar strain. Complete relief.

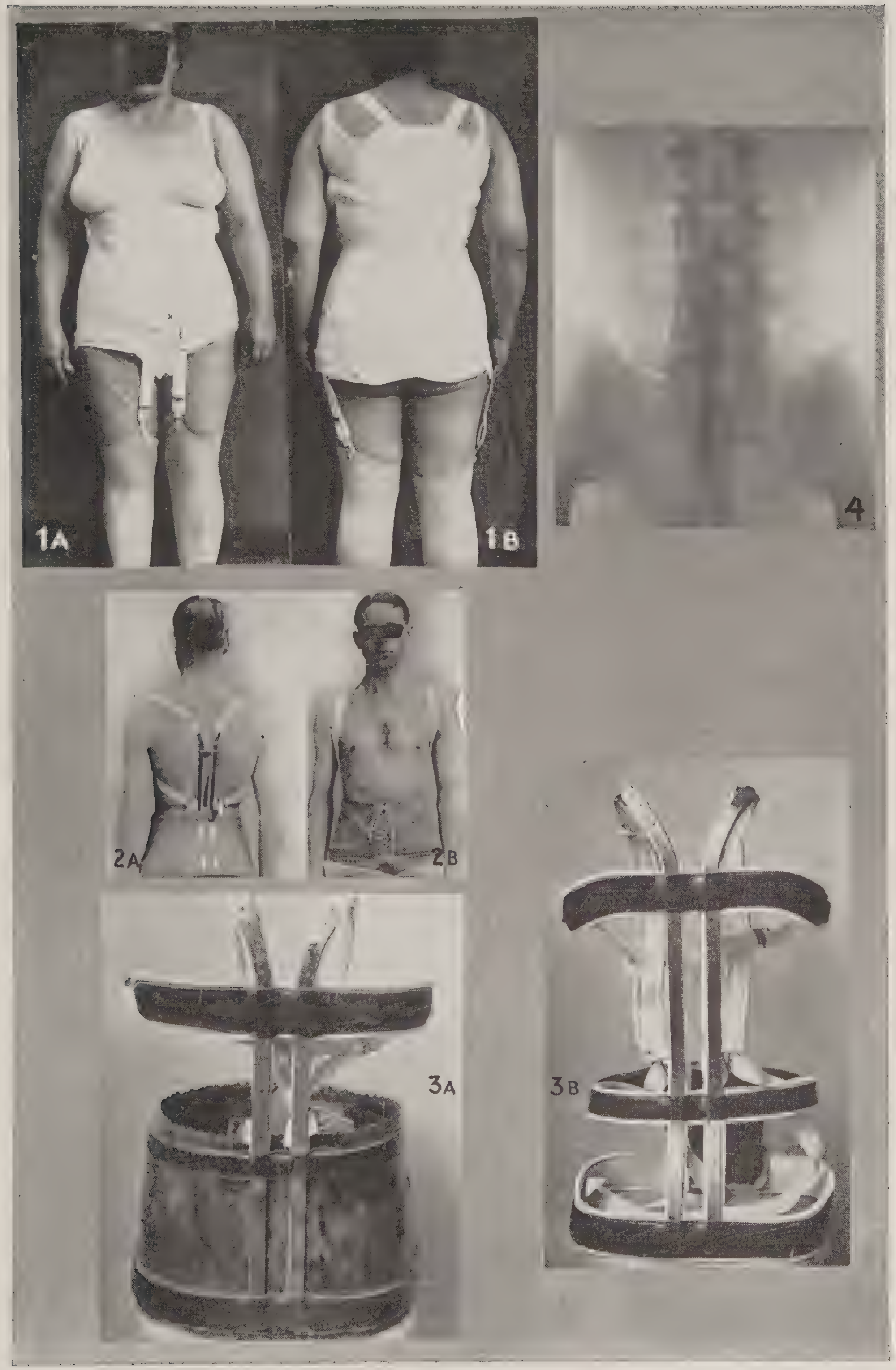

PLATE L

to the base and kept from wrinkling by insertion of light steel strips. It gives enough support to the pelvis to relieve the symptoms. Such belts can be made more effective by adding a felt pad in the back which makes pressure upon the upper end of the sacrum (Plate L, 2, 3).

(4) *Plaster of Paris Jackets.*—Plaster of Paris jackets are used to best advantage in acute cases well enough to relinquish the recumbent position. The jacket must be well fitted over the buttocks and anterior portions of the pelvis. The top of the jacket should be carried well up to the shoulders in order to hold the spine hyperextended and at the same time to prevent the lower part of the jacket from riding up and releasing its hold upon the pelvis. If the pelvis does not appear sufficiently immobilized by the jacket, the plaster should be carried down to the thigh as a spica bandage, or, in extreme cases, both thighs should be included in the cast. If the case is one of injury rather than one of simple strain, this arrangement is especially useful. Fixation is necessary from two to four weeks, part of which time the patient must spend in bed and part of which he is allowed to be up. A removable appliance such as a brace or belt is applied afterward during the convalescent stage.

All sprains not likely to yield to the relative insecure immobilization by either straps or belts are to be treated by plaster casts. In joint sprains or relaxation without displacement of the bone, which represent a large proportion of the total number of cases, some support is all that is necessary, and there is little need for interruption for the usual routine of life (Goldthwaite[37, 38]).

The best position for the application of the jacket is with the patient standing, and arms raised above the shoulders.

b. The Secondary Ambulatory Treatment.—When releasing the patient from the recumbency and beginning the ambulatory treatment, the change should be a gradual one. After being fitted with his retaining apparatus or plaster, the patient must be put on crutches. Weight bearing in unilateral cases is further excluded by a higher heel placed under the sound foot. Elimination of weight bearing in the first stage of ambulatory treatment is an important feature, especially in the acute sacroiliac sprains. While in sacrolumbar sprain the patient is able to guard himself pretty thoroughly against weight-shifting and can maintain his spine well immobilized by muscle contracture, he cannot do so as a rule in the sacroiliac sprain. Here, whenever the body weight is received wholly by the standing leg, it produces a very painful shearing stress in the sacroiliac articulation, and hence it is necessary to use crutches. After the patient has been up in cast, belt, or strapping, he is gradually permitted to bear more and more weight until he is able to discard the crutches entirely. This may take from a few weeks to several months. The patient is then supplied with a definite well-fitting sacroiliac belt which he is to wear for at least one-half year or longer. To the fitting of this belt and especially to the manner in which the pad is fastened, a great deal of attention should be paid. The pad must fit snugly in the hollow between the ossa ilei and must nestle closely over the articulation with a broad strip of webbing holding it in place. For the sacrolumbar belt, the type reaching high up at the back and fitted with shoulder straps is preferred as it gives the entire body the proper position of relief (Plate L, 1).

3. Manipulative Treatment

The object of treatment is both reduction of the sacroiliac subluxation and the breaking of adhesions. With the exception of very rare cases of formidable injury, such as the falling of a great load of earth or slate upon the back, or when the body is pinned under a car, i.e., with the exception of cases in which there is an actual avulsion fracture of the sacroiliac synchondrosis, such subluxation is not demonstrable. Only one case of this kind was observed in the writer's series. The impossibility of x-ray demonstration does not preclude the existence of a relaxation of the joint. The manipulative treatment is indicated in cases of persistent malposture, or persistent pathologic attitudes and periodical relaxation with signs of local and radiating pain.

The usual manipulation consists in acute flexion of the hip and extension of the knee whereby a pull is exerted upon the tuber os ischii through the hamstrings. The result is, that the os ilei is forced backward upon the sacrum in direction opposite to that of the original strain. It is at that moment that an occasional click is felt by the patient.

The correction of the relaxation can be brought about also by direct pressure upon the sacrum, sometimes by simply hyperextending the spine and having the patient lie with a firm pillow under the hollow of the back; one may then by lordosing the lumbar spine draw the sacrum into place. At other times it can be accomplished by having the patient lie face downward with thighs and legs supported upon the table and head and shoulders upon another, so that the body swings unsupported between. In this position the weight of the body drags the spine forward favoring the replacement of the sacrum. If the replacement is successful, a plaster jacket is applied which holds spine and pelvis in place.

For the application of the plaster cast the Goldthwaite frame is very practicable. It places the patient in a position where the weight of the body tends to throw the sacrum forward. (See Chapter VI.)

4. Nerve Stretching

In persistent cases of sciatic pain forcible stretching of the sciatic nerve is indicated. It is carried out in the same manner as the replacement maneuver in sacroiliac subluxation. A pull on the tuber os ischii through the hamstrings is here also accomplished by sharply flexing the hip and extending the knee at the same time. Following the manipulation of stretching the patient is held in bed for a few days and is then allowed to be up on crutches. The indication for nerve stretching is persistent sciatic pain.

A distinction should be made between radicular involvement of the sciatic nerve, that is, of the intrapelvic portion, and sciatica of the nerve trunk. If the sciatica concerns the trunk, then upon intraneural injections of normal saline or novocaine the pressure points disappear; if, on the other hand, after injection pressure tenderness is still present, it tends to prove that the roots of the plexus are involved also (Wiedekopf[99]). In the latter event the stretching is less promising, as it does not exert sufficient pull upon the pelvic portion of the sciatic trunk.

Stretching of the sciatic nerve is accompanied by a fall of the temperature of the extremities, quickly followed by a rise which may last as long as sixteen minutes.

Experiments show also that novocaine injections, as well as nerve stretching and neurolysis, produce a long-continued increase in temperature in the area of the distribution of the sciatic nerve. From this it is concluded that in all these procedures the sciatic hyperemia produced plays an important part in the curative effect. Injections of the sciatic nerve with novocaine and normal salt solution have been tried with various results. Hertzler[51] finds injections of 15-30 c.c. of 1 per cent quinine urea most effective. Of this 5 c.c. are injected directly into the nerve, the rest into the vicinity. In milder cases one injection suffices, in severer four to five at intervals of two to three weeks are necessary. Stoffel's method is one of resection of the superficial, median and lateral cutaneous nerves (Vollhardt[95]). This method is applicable only to severe cases in which all other measures have failed.

Open stretching can be accomplished by exposing the nerve from an incision starting from the gluteal fold downward or by the incision of Guy deFrenelle which opens an approach to the nerve from its point of exit out of the lesser pelvis at the lower border of the pyriform muscle. The nerve is stretched centrally as well as distally and at the same time the superior and inferior gluteal nerves are freed from pressure at the lower edge of the os ilei. The short branches of the lumbar plexus and the already mentioned posterior rami to the spinalis muscles are likewise stretched.

As a rule sciatica caused by derangement of the sacroiliac joint and by traumatic or inflammatory adhesions yields to stretching, either manipulative or operative.

For two weeks to twenty days following the open stretching operation there is noted an exacerbation of pain especially of evenings. The after-treatment consists in faradization, massage, and after ten days to two weeks the patient is allowed to leave the bed. After bloodless stretching the patient should not be allowed to be up as long as he has pain while in the recumbent position and no exertion is to be permitted for a considerable length of time. As the sciatic pain disappears the scoliosis also disappears.

Even in severer cases of sciatica the prognosis is not particularly bad. It is of importance to note whether or not the scoliosis disappears under deep anesthesia; if it does, the prognosis for early subsidence of sciatic pain after stretching is good, while in the other event a longer time will probably elapse before the sciatic pain subsides.

5. Treatment of Inveterate Cases

Long persistent sprains of either the sacroiliac or the sacrolumbar junctions are much harder to manage not only because of their chronic character but also because they are prone to exacerbation on the slightest occasions. The periodic attacks are difficult to control and recurrences may be just as violent as in the most acute cases. The writer has observed many cases with inveterate chronic disability of the sacroiliac joints in recurrent attacks screaming with pain and actually unable to move. In these periods of recrudescence the treatment differs little from that already described for the acute sacroiliac or sacrolumbar sprain. It is best to institute the conservative treatment by bed rest, immobilization, extension, and to add later the stretching of the painful nerve. This is to be followed by immobilization in casts, and crutches.

In the course of time a chronic relaxation of the joint may develop so that it becomes utterly impossible for the joint to sustain the normal stresses for any length of time. Accordingly we find that a number of cases remain wholly refractory to conservative treatment and for these the operative methods of treatment must be chosen.

6. The Operative Treatment

a. Operation upon the 5th Lumbar Transverse Process.—The question as to the significance of impingement of the 5th lumbar transverse process upon the os ilei has already been discussed.

From time to time these processes have been removed under the impression that they are responsible for the clinical syndrome. It is also believed by many that in cases of sacralization associated with Bertolotti's[11] syndrome complex, the removal of the anomalous transverse process is the proper surgical procedure (Adams,[1] Goldthwaite,[39] Kleinschmidt).

Technic.—From an incision 15 to 18 cm. in length running longitudinally downward and somewhat outside the posterior superior iliac spine, the lumbar aponeurosis is divided and the muscle masses of the sacrospinalis muscle are retracted. Gradually, access is gained to the transverse process by subperiosteal dissection. The apophysis is isolated, care being taken not to injure the lumbar cord which runs in front of the transverse process. After the transverse process has been carefully isolated, both from the iliosacral end and from its base, it is then stripped free and removed with hammer and chisel (Baumann[7, 8]).

It is only rarely, however, that such a strain can be localized definitely within the narrow field surrounding the 5th lumbar transverse process. It is much more likely that chronic strain even if primarily based upon anatomic variations, ends up with a general relaxation of the ligaments of the whole region so that the limited, though very difficult operation of the removal of the transverse process, is very uncertain.

b. Fusion Operations.—Of greater promise seem to be the fusion operations of the sacrolumbar and sacroiliac articulations, which, by eliminating motion entirely, meet the problem of ligamentous relaxation in a radical manner.

(1) *The Sacrolumbar Fusion.*—(a) Method of Hibbs. (See Chapter VI.) One must obtain a good exposure of the sacrolumbar articulation and the articular processes which often lie quite laterally to the midline and therefore, require very patient and careful dissection. The articulation between the 5th lumbar and the sacrum are curetted out and heavy bone bridges are recovered from the neural arches of the 5th lumbar and the sacrum, and finally the spinous processes are broken down. In order to secure further reliable fusion between these articulations, additional implantation of living bone or beef bone may be used.

Sacrolumbar fusion is indicated not only in simple sprain of the sacrolumbar region, but also in cases of spondylolisthesis (see Chapter I).

The aftertreatment is similar to that which applies to fusion operations for scoliosis or tuberculosis of the spine. This means recumbency for a period of six to eight weeks until the fusion is solid, and then immobilization in a plaster cast for a period from three months to one-half year.

(b) Method of Albee (See Chapter VI).—In Albee's method of sacrolumbar fusion, an autogenous bone graft is mortised into the spine of the last lumbar process and into the sacrum similar to the technic described for tuberculosis of the spine (Chapter VI; Plate L, 4).

(2) *The Sacroiliac Fusion.*—(a) Smith-Petersen's Technic.—Smith-Petersen's[90, 91] method is most widely used (Plate LI). Incision is made along the posterior two-thirds of the iliac crest curving around the posterior superior spine and then running parallel to the fibers of the gluteus maximus downward for a distance of two to three inches. This incision is deepened into the periosteum, and the outer table of the os ilei is subperiosteally exposed. Upon this surface the sacroiliac joint projects itself in the form of a double or broken rectangle, the inferior border of which runs parallel to the sacrosciatic border of the os ilei (Plate LI, 1). One then cuts a window one and one-half inches long and one inch wide with the long horizontal side parallel to the edge of the os ilei. The window is deepened until one reaches the articulation. A block of bone is thereby recovered which can be lifted out and which shows on its inner side the articular surface of the os ilei, while in the depths of the hole the articular surface of the sacrum becomes visible. It is now very easy to destroy the articulation by curetting the sacrum and removing the fibrocartilaginous covering of the bone block removed from the os ilei. The hole is then further deepened until it reaches well into the substance of the sacrum, and then the bone block is reinserted, acting as a peg which unites sacrum and os ilei. This peg is then countersunk by a few taps of the hammer so that its cancellous surface comes into contact with the cancellous bone of the sacrum. Then by osteotomy cuts made from the edges and by accumulated bone chips placed upon the countersunk block, the joint is held in position (Plate LI, 2). The patient is put in an immobilizing cast and remains in bed for four to six weeks. He is then allowed to be up in a plaster cast applied for two to three

months and finally is fitted with a convalescent belt or brace which he should wear for another half year (Plate LI, 3, 4). In women in whom the subluxation of the sacroiliac joint is often associated with conditions of congestion and relaxation of the pelvic organs, it is advisable to have the pathologic condition of the organs corrected first before the joint itself is treated.

(b) Gaenslen's Technic.—In the technic of Gaenslen[36] the joint is approached more directly from an incision made over the posterior third of the crest and posterior superior spine. The os ilei is split from the posterior crest forward into an outer and a thin inner leaf, the outer leaf is deflected outward, the articulation is outlined on the inner leaf and exposed by removing from it a triangular piece; the joint is curetted out and the hole filled with bone chips.

TABLE IV

TREATMENT TABLE

TOTAL 170 CASES TREATED

Type of Treatment	Sacroiliac Cases Treated 113				Sacrolumb. Cases Treated 29				Combined Cases Treated 28				Sum
	Good	Fair	Poor	Total	Good	Fair	Poor	Total	Good	Fair	Poor	Total	Total
Recumbency & Traction	7	1		8	3			3		1		1	12
Supports Belts, Casts Braces	64	14	5	83	22		3	25	16	6	4	26	134
Oper. Manip. Stretching	7	3	3	13									13
Oper. Fusion	8	1		9	1			1	1			1	11
TOTAL	86	19	8		26		3		17	7	4		170

7. Duration of the Treatment

The length of time required for the treatment depends upon many factors which vary with the individual case. In simple sprains without displacement, strapping for three or four weeks followed by a corset or a belt for a few more weeks will be all that is necessary. In conditions of acute injuries, the treatment is the same, only that it must be kept up for a longer period.

In cases of relaxation associated with pregnancy, the patient may be allowed up in a support three weeks after delivery (Goldthwaite). The support should be worn until two or three menstrual periods have passed.

In relaxed cases associated with menstruation it may be necessary to wear some sort of support for an indefinite period (Goldthwaite).

PLATE LI

Fig. 1.—Incision and preparation of bone cut (after Smith-Petersen).

Fig. 2.—Details of removing, denuding and counter-sinking bone block. (After Smith-Petersen.)

Fig. 3.—Patient with persistent sacroiliac strain before Smith-Petersen operation.

Fig. 4.—Same patient after operation. Complete relief. (Note symmetrical posture.)

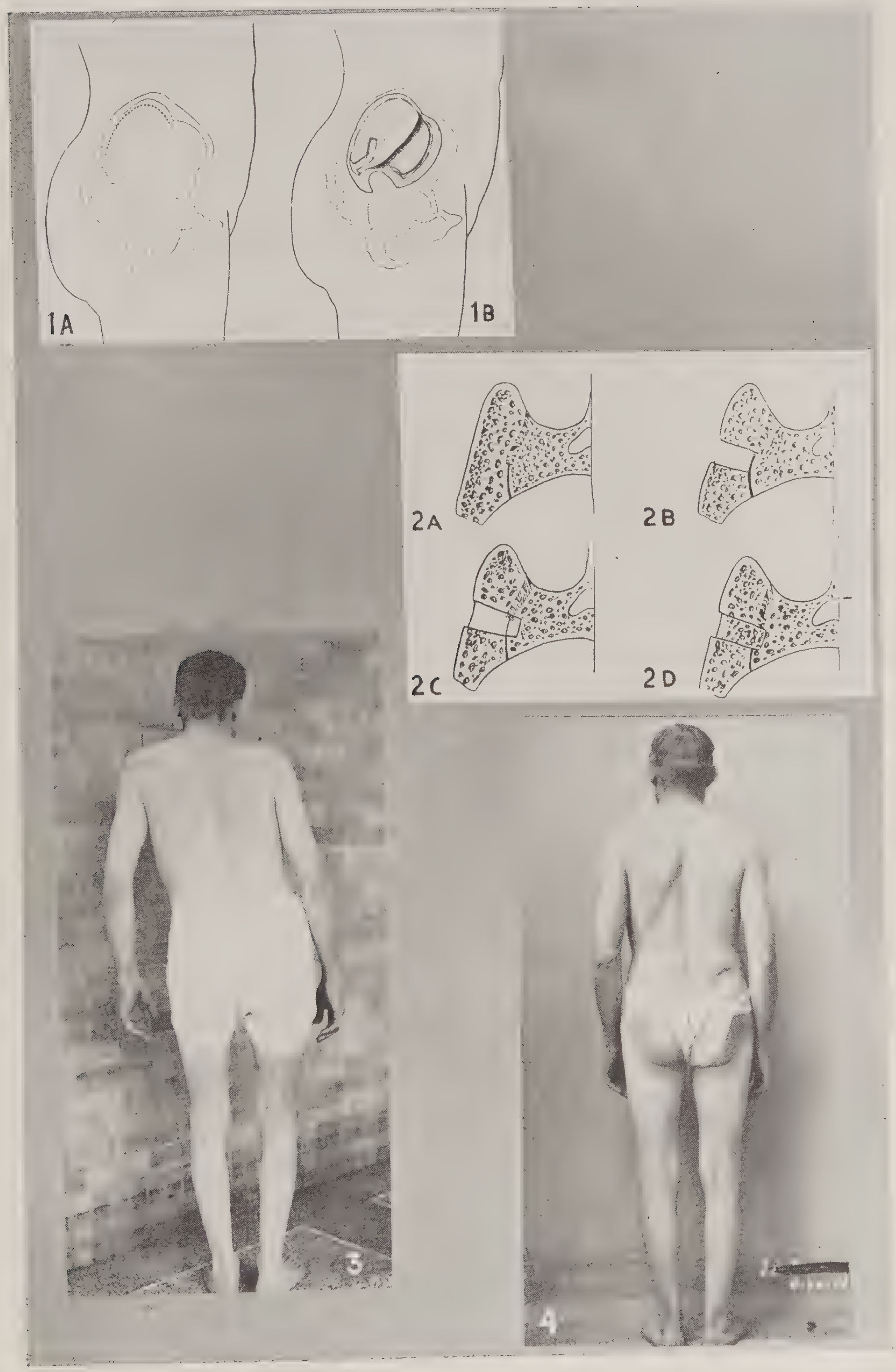

PLATE LI

In cases requiring manipulative treatment support in plaster of Paris cast for elimination of weight bearing will be necessary for two to three months, and must be followed by convalescent belt or brace to be worn for half a year.

In cases operated upon by fusion, recumbency is necessary until the fusion becomes solid and this means six to eight weeks in bed, and immobilization for one-half to one year (Table IV).

VIII. COMMENT ON CHAPTER V: LOW BACK PAIN

From the diagnostic point of view, differentiation between symptomatic and so-called idiopathic low back pain is the important point. The greatest difficulty in differentiation is offered by the arthritic conditions of the spine.

The analysis of the local pain itself and the allocation of its origin to the different parts of the lower back is comparatively easy, and, thanks to the typical features of sprains, rather reliable. The correct diagnosis of the particular sprained structure should be arrived at from a systematically conducted examination.

Secondary symptoms arising from the plexus offer more difficulties. On the side of treatment a distinction must be made between a remediable ligamentous sprain and permanent relaxations. The latter are objects for operative fusion.

Secondary sciatic symptoms should yield to immobilization in a large measure; to immobilization plus stretching in the majority of cases.

Errors commonly made in the treatment are of two kinds: first, that measures are being trusted for immobilization which are obviously insufficient; belts are applied, where braces or casts are needed; or braces, where recumbency is required. Secondly, weight bearing is often allowed too soon; especially during the transition period from the recumbent to the ambulatory stage must crutches be used.

Under the application of recognized principles, both diagnostic and therapeutic, the field of mechanical derangements of the lower back is one of the most exact and gratifying ones in orthopedic surgery.

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CHAPTER VI

TUBERCULOSIS OF THE SPINE

Synonym: Caries Vertebrae, Pott's Disease

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INTRODUCTION

Under the title of: "A Marked Palsy of the Lower Limbs Which Is Frequently Found to Accompany Curvature of the Spine and Supposed to Be Caused by It," there appeared in 1779 a treatise by Percival Pott which is considered the first authentic description of spinal tuberculosis.

According to Ridlon,[154] Pott's publication was preceded by a report from Jean Pierre David,[50] apparently dealing with a case of tuberculous spine. The priority, however, is generally conceded to Pott and the name of Pott's disease has found acceptance in English and French literature.

I. PATHOGENESIS

It is all important to consider tuberculosis of the spine as a manifestation of a general tuberculosis.

1. Pathogenetic Development; Stages

The primary tuberculous lesion is acquired in early infancy, in most cases during the first three years of life (Peterka[143]). In the greatest number of the afflicted the primary infection heals completely and so we find evidence of healed tuberculosis in 90 per cent of autopsies performed on persons who died from all causes (Ghon[72]). In a certain number of cases, however, the primary lesion spreads (Aschoff[11]) by involvement of the regional lymph nodes. A stage then develops which is called by Aschoff the anaphylactic period of phthisis. From the lymph nodes the lungs are again infected (secondary stage). During this stage of generalization a portion of infants and young individuals succumb. In others, however, the process comes to a halt and remains latent at this stage. Still in others metastases are produced from these lymph nodes in distant portions and organs of the body. We have then a visceral tuberculosis, that is, the metastatic infection of bones, kidneys, urinary system, etc., which develops as a rule in early adolescence and sometimes in early infancy. Again, a reinfection of the lungs from these lymph nodes may occur later in adolescence or in adult life. This is a point of great importance for the understanding of the pathogenesis of bone tuberculosis. It explains the relation between pulmonary and spinal tuberculosis which exists later in life. We have, then, a primary involvement of the lungs in early infancy as the primary stage; next the involvement of the lymph nodes, the reinfection of the lungs in the secondary stage; metastatic involvement of the viscera and bones in infancy and puberty and metastasis in the lungs in adolescence or later life, as the tertiary stage.

There is always the possibility that a latent infection from the secondary stage, being prolonged into adult life, may cause a generalization of tuberculosis without an additional infection from the outside. Then we see skeletal tuberculosis develop as late as the 4th and 5th decades of life and even later, due to a long latency of a secondary focus which existed for many years and the beginning of which goes back to early infancy.

II. FREQUENCY STATISTICS OF SPINAL TUBERCULOSIS

1. General Frequency

It is especially interesting to note that consumption in infancy is not decreasing in the same proportion as is that of the adult. From this it appears likely that our hygienic measures for prevention of tuberculosis merely serve to ward off reinfection in later life but do not affect primary infection. On the other hand, the prevention of primary infection in child or adult would leave man unprotected in later life and more exposed to an attack of even greater virulency since he has acquired no immunity.

The great increase of the frequency curve of tuberculosis in children, latent or manifest, due to early acquisition of primary tuberculosis appears from the following statistical data: In children under one year, Pirquet[147] and Hamburger[81] find no positive tuberculin reaction, either cutaneous or subcutaneous; between the years of two and four, the figures reach 13 to 26 per cent, and between the ages of ten and fourteen from 70 to 90 per cent, respectively, for the cutaneous and subcutaneous tests.

From the same tests Freer[65] and Bass[18] find the following percentages: up to six months, cutaneous 1 per cent and subcutaneous 7 per cent positive; from three to five years 20 per cent cutaneous and 42 per cent subcutaneous; from five to six years 78 per cent positive.

According to autopsy findings made on children (Comby, quoted by Sauer[168]), tuberculous lesions are found in 38 per cent of all, ranging from 1.8 per cent in children under three months to 71 per cent in children up to fifteen years. In the statistics of Ghon[72] tuberculous lesions in the lungs of children were found at autopsies at a still higher percentage.

2. Frequency of Spinal Tuberculosis

a. Relative to Hospital Population in General.—Wullstein[211] finds among 100,000 cases of a large surgical clinic, 0.365 per cent of spinal tuberculosis. The combined statistics of Billroth,[24] Hoffa,[90] Lorenz,[119] Mohr,[129] and Wullstein,[211] aggregating 287,000 surgical cases give a ratio of 0.409 per cent.

b. Orthopedic Incidence.—Relative to the number of orthopedic patients Wallace[204] finds the frequency ratio to be 1.5 per cent among 148,000 orthopedic cases. Various other statistics give the incidence of spinal tuberculosis among orthopedic conditions between 1.5 to 12.9 per cent (Hoffa and Wullstein), the average being somewhat less than 10 per cent. Figures in this country are apt to be much lower. The ratio of the author's series is 2 to 3 per cent of all orthopedic cases.

The frequency ratio of tuberculosis of the spine to autopsy findings of all kinds is shown in a combined table which includes 47,000 autopsies (Billroth and Menzel[24]). This table gives the incidence of tuberculosis of the spine among all autopsies as 1.48 per cent.

c. Incidence in Surgical Tuberculosis.—The ratio of tuberculosis of the spine to surgical tuberculosis in general is given variously from 30 to 50 per cent. Valtancoli's[196] figures are 45.5 per cent, those of the Hospital for Ruptured and Cripples (N. Y.) 39.6 per cent; of the Boston Children's Hospital 50 per cent. The writer's series shows a ratio of 30 per cent.

Neither clinical nor autopsy statistics present more than an approximate indication of actual conditions, the former because of the percentage of erroneous diagnoses and the latter, because the autopsy material is hardly representative of all sufferers from spinal tuberculosis. One may assume that the frequency of tuberculosis of the spine (1.5 per cent) among the hospital population is considerably higher than that of civil life.

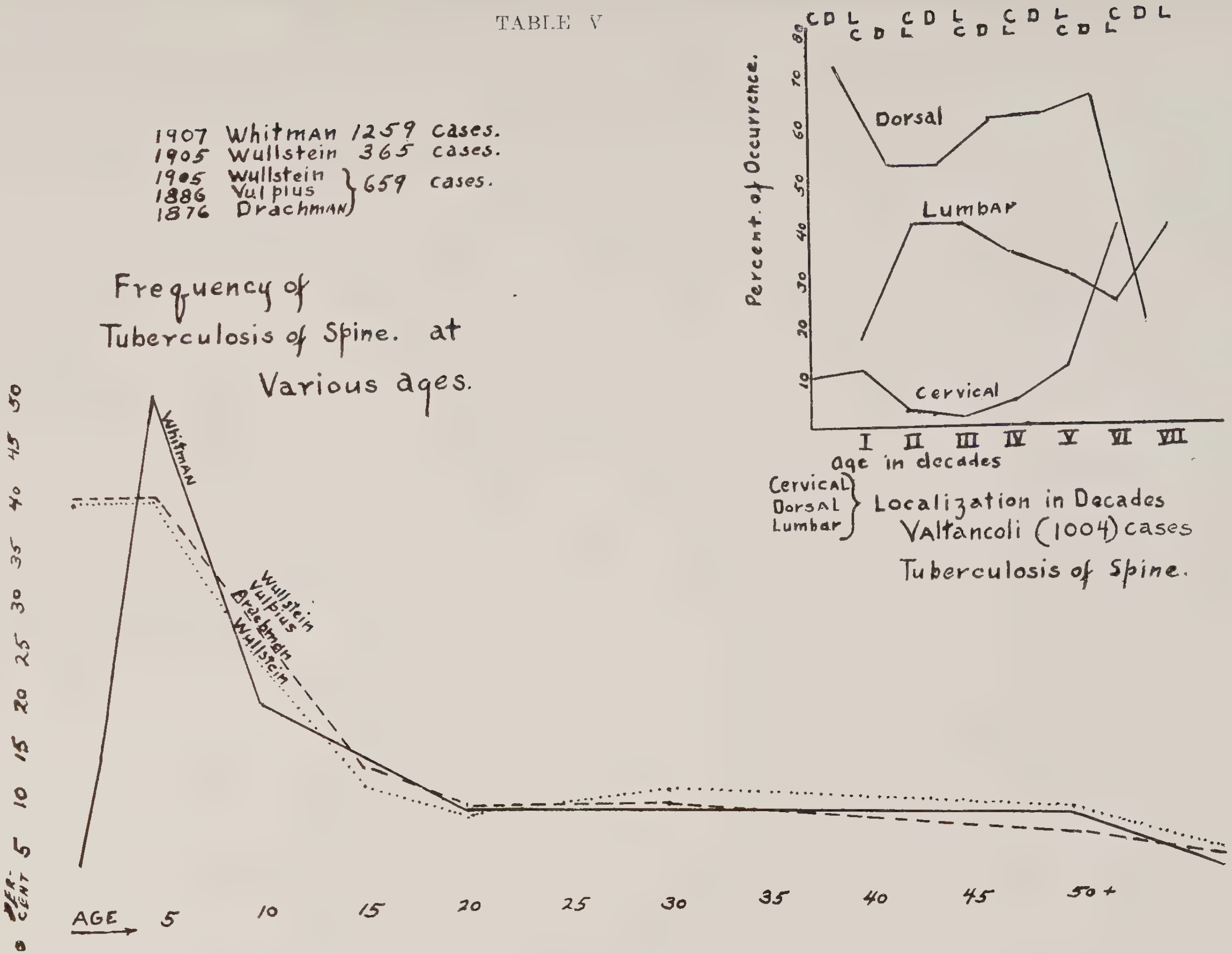
3. Frequency of Spinal Tuberculosis Relative to Other Factors

a. Age.—Tuberculous spondylitis, as tuberculosis of the skeleton in general, is largely a disease of the growing bone. The higher incidence in growing years is, however, not so overwhelming, but that it leaves a rather wide berth for later decades, in which the disease is not at all uncommon.

The age statistics arranged by decades, as usually given, are somewhat misleading as to the force of incidence of tuberculosis in later years. They do not take into account the factor of vital statistics, that is, the ratio of all people attaining a certain age to all people born alive. This error, while insignificant in earlier decades, becomes considerable when the more advanced ages of fifty or sixty are reached. Therefore, the figures given for later decades are generally too low (Table V, a). In the combined tables of Wullstein,[211] Vulpius,[201] Drachmann, and Mohr,[129] 14.7 per cent of the patients were older, and 85 per cent of the patients younger than twenty years. Of these again the period from four to ten years shows the highest frequency, namely, 65.8 per cent of all cases.

b. Frequency of the Site of Vertebral Tuberculosis.—The numerical comparison between cervical, dorsal, and lumbar sections does not give a correct impression of the distribution because of the greater length and the greater number of vertebrae in the dorsal section of the spine. It is better to compare the combined figures for cervical and lumbar sections with the dorsal.

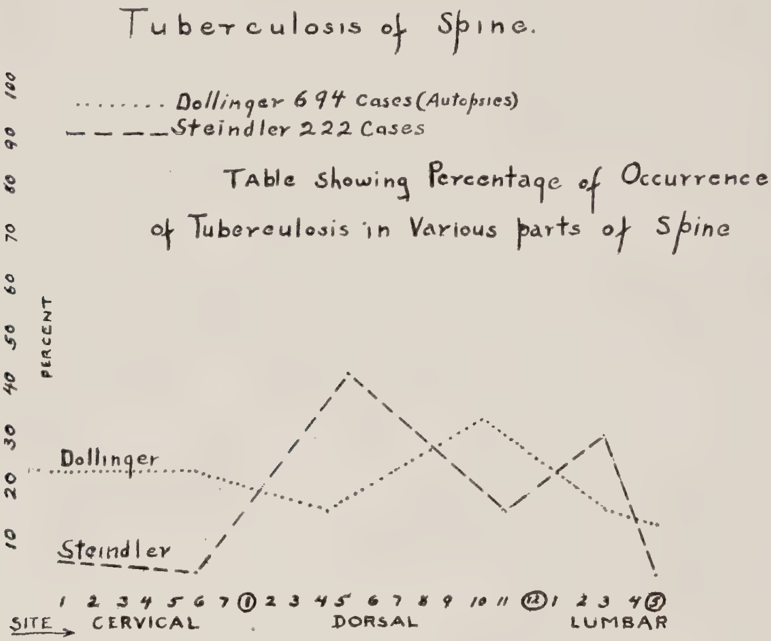
TABLE V


1907 Whitman 1259 cases.
1905 Wullstein 365 cases.
1905 Wullstein
1886 Vulpius
1876 Drachman } 659 cases.
Frequency of
Tuberculosis of Spine. at
Various ages.
Whitman
Wullstein
Vulpius
Drachman
Wullstein
PER CENT 0 5 10 15 20 25 30 35 40 45 50
AGE 5 10 15 20 25 30 35 40 45 50+
C D L C D L C D L C D L C D L C D L C D L
Percent. of Occurrence.
10 20 30 40 50 60 70 80
Dorsal
Lumbar
Cervical
I II III IV V VI VII
age in decades
Cervical
Dorsal
Lumbar } Localization in Decades
Valtancoli (1004) cases
Tuberculosis of Spine.

A predilection for localization can be recognized in certain circumscript regions. Both the clinical and autopsy observations agree on a preponderance of involvement of the dorsal spine; next is the lumbar and last in frequency is the cervical spine. Clinical figures (Dollinger[58]) show 12 per cent for the cervical, 60 per cent for the dorsal, and 28 per cent for the lumbar spine.

Autopsies (principally based upon the statistics of Billroth and Menzel) show: 26 per cent in the cervical, 53 per cent in the dorsal, and 19 per cent in the lumbar spine. The author's figures are 6.9 per cent for the cervical, 3 per cent in the cervicodorsal, 42 per cent in the dorsal, 15 per cent in the dorsolumbar, 30 per cent in the lumbar, and 2.6 per cent in the sacral sections (Table VI).

TABLE VI



Double localization of tuberculosis, i.e., secondary foci in the spine are very rare. According to Peabody[142] they are found in only 4.1 per cent of all spinal tuberculosis. The majority of lesions occur below the primary focus, and are probably caused by contact infection from the gravitation abscess.

c. **Frequency and Sex.**—There is no great difference in the distribution among sexes, in both the tuberculosis prevails in the dorsal region; in the male the figures for the dorsal spine are somewhat lower, and those for the lumbodorsal localization somewhat higher than in the female (Valtancoli[196]).

d. **Age and Site.**—If the age and site are correlated one finds as follows: In the first decade the dorsal tuberculosis greatly preponderates, while the frequency of lumbar localizations is comparatively low; in the second decade there is a drop of the dorsal and a considerable rise of the lumbar and lumbodorsal localizations; in the third decade again, the dorsal form prevails, but the lumbar type, too, remains frequent. Cervical and cervicodorsal forms are greatly diminished in frequency. In the fourth decade again, we find prevalence of dorsal forms especially the cervicodorsal and lumbodorsal; in the fifth decade again, there is prevalence of the dorsal form, but cervical types again assume greater frequency. This increased frequency of the cervical type is still more pronounced in the sixth decade, though the dorsal site still remains most frequent; in the seventh there is prevalence of the lumbar and cervical locations (Table V, b).

e. Statistics on Heredity.—That heredity is of considerable influence upon the development of spinal tuberculosis seems certain. The statistical data covering this point are so divergent, however, that it is difficult to arrive even at an approximately accurate impression. The figures in the literature vary from 76 per cent (Gibney) to 10 per cent. Vulpius[201] estimates 16.6 per cent; Lorenz,[119] 27 per cent; Valtancoli,[196] 13 per cent; the author's figure is 21 per cent.

f. Trauma and Spinal Tuberculosis.—Of great interest is the significance of trauma as a causative or predisposing factor. It was Delpech, who first pointed to the connection between Trauma and Tuberculosis of the Spine. Naturally, not all injuries mentioned in the history can be taken into account. On the other hand, frequent injuries, even if not of a very violent nature, in a relatively feeble body, especially if occurring during the period of rapid growth must be taken into consideration. This may explain why between the ages of eleven and fifteen the female sex predominates in spinal tuberculosis with 56 per cent against 43 per cent; while in the next five years, that is, between fifteen and twenty, the male sex preponderates with 63 per cent against 37 per cent. Delitala[54] reporting on 500 cases of spinal tuberculosis from the Institute Rizzoli found the percentage of trauma to be between 5 and 10 per cent. The author's statistics show a much higher percentage, namely, in 25 per cent among 232 cases in which data were obtained. The figures of Taylor[187] are as high as 53 per cent. This variation in percentages depends largely upon the interpretation of trauma. How is one to assess it as a factor in spinal tuberculosis? If only such incidences are included which by their manner of occurrence or by their frequency appear to have a causal connection with the disease, it is likely that the figures from 7 to 10 per cent would come nearest to the truth. According to Loeffler[118] it is necessary in order to establish the connection between the two events, that tuberculosis appear shortly after trauma, showing thereby, that either a manifest focus has become worse or a latent focus has become manifest. The trauma causes a point of lesser resistance, but it cannot directly produce a tuberculous focus. It must be assumed that such a focus preexists, but has remained dormant and is merely becoming manifest after the trauma. At any rate a suitable interval, of one month at least, or six months at the most, should elapse after the immediate effect of the accident has passed, and before the first sign of surgical tuberculosis appears, if trauma is to be considered as an etiologic factor in tuberculosis of the spine.

Experimental studies of Petrow[144] have brought out the fact that bacilli may circulate in the bone marrow without causing a reaction, but that the trauma favored and facilitated in a manner histologically demonstrable the local eruption of tuberculosis. Clinically it was likewise proved that the traumatic influences are able to direct the localization of tubercle bacilli from the blood stream to the traumatized tissue (Schüller[174] and Krause[110]). Trauma, therefore, is considered a factor which favors the recrudescence of tuberculosis in an already settled, though quiescent, area (Lannelongue,[114] Honsell,[92] Delitala[55]). So far as the production of tuberculosis by trauma in a heretofore healthy joint is concerned, the experimental findings uniformly refute such a possibility, and in accordance with the laboratory findings the clinical investigation also points to trauma as an aggravating factor only, which may produce an unexpected rapid course of tuberculosis, and which may cause a latent tuberculosis to become manifest.

III. GENERAL PATHOLOGY

1. Predisposing Conditions.—A distinction should be made between purely predisposing intercurrent diseases which have an effect upon the general health and which lower the patient's resistance, and true tuberculous complications in other parts of the body. Prominent among predisposing general infections are contagious diseases such as measles, influenza, scarlet fever, whooping cough and typhoid. Others, not belonging to the contagious group, are pneumonia and nontuberculous pleurisy, the latter being found by Valtancoli[196] in not less than 21 per cent of the cases.

2. Complicating Tuberculous Conditions in Other Parts of the Body.—It is to be remembered that patients with spinal tuberculosis are tuberculous individuals who have acquired a primary lesion early in infancy or in prepuberty life; individuals in whom the disease has entered the stage of generalization resulting in the diffuse caseation of bronchial lymph nodes and later in the spread of metastases to bone and joints and to the viscera of the body. It was mentioned in the section on Pathogenesis that pulmonary reinfection occurs later, being more frequent in adolescent and in adult life. In later years, again, concomitant pulmonary tuberculosis becomes less frequent (Valtancoli[196]). In the author's series 17 per cent of the cases of spinal disease showed concomitant pulmonary tuberculosis.

IV. SPECIAL PATHOLOGY OF TUBERCULOSIS OF THE SPINE

1. Mechanism and Routes of Infection

The metastases involving the skeleton have been designated as tertiary stages of tuberculous disease. Through the primary and secondary stages a certain immunity is acquired which is not without influence upon the course and outlook of the later developing surgical tuberculosis.

The usual route by which skeletal metastases develop is the hematogenous one. The vascular distribution determines the localization of tuberculous foci. Direct infection from open wounds is very exceptional.

As to the manner of infection, Volkmann and Koenig[107] drawing their conclusions from the wedge-shaped tuberculous foci often seen within the vertebrae assumed it to be of the embolic type. Lexer,[116] however, proved that the most important factor for the localization is the anatomic distribution of the arterial system. Following the example of Koenig he studied the blood supply to the large joints, the long bones, and the vertebrae. In the latter he finds three zones of arterial distribution corresponding to three distinct types of localization of tuberculosis. They are the anterior peripheral, the central and the epiphyseal distribution (Plate LII, 1). The anterior portion of the vertebra is supplied by multiple small vessels entering into the body of the vertebra from the anterior longitudinal ligament. The body of the vertebra itself is supplied by a pair of comparatively large arteries entering into the posterior portion of the vertebral body and supplying most of the body substance. A third pair, also coming from the posterior branches, takes an up- and downward course and ends in the epiphyses of the vertebra.

The arterial supply of the neural arches is represented by a pair of arteries which enter into the bases of the transverse processes. These arteries supply the pedicles, the neural arches, the transverse and spinous processes. In the young vertebrae the arterial supply between posterior arteries and arteries of the bodies are strictly separated and there are no anastomoses. In the adult, however, there are ample anastomoses both between the arteries supplying the vertebral bodies, the epiphyses, and the arterial supply of the neural arches and pedicles. Hence, in children we find the most frequent localization in the bodies of the vertebrae, and in adults in the epiphyseal end-plates and at the anterior surface of the body.

2. Topographical Types of Spinal Tuberculosis

In accordance with this distribution of the blood supply in juveniles and adults the following pathologic types can be distinguished: (a) the central form, (b) the anterior peripheral form, and (c) the epiphyseal form.

In the central form, the body of the vertebra itself, or the portion supplied by the posterior arteries which enter into the body underneath the posterior longitudinal ligament, is involved. In the peripheral form the anterior portions of the body under the anterior longitudinal ligament are affected, and in the epiphyseal form the peripheral portions of the vertebral bodies adjacent to the epiphyseal discs are the seat of the disease.

a. **The Central Type (Plate LII, 2).**—This is the most frequent form in children. For a long time, foci may remain latent in the vertebral body until the destruction has proceeded to the point where the center of the body collapses under the body weight and the gibbus appears. Later the destruction passes on to the epiphyseal ends of the vertebrae leading to disorganization

PLATE LII

Fig. 1.—A diagram of the three zones of distribution: anterior peripheral, central, and epiphyseal. (After Wullstein.)

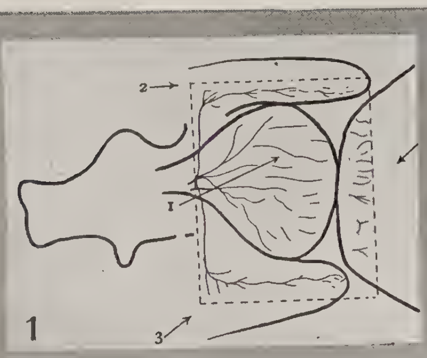
Fig. 2.—Central type of tuberculosis of the body. (Note the destruction of the body and collapse.)

Fig. 3.—Epiphyseal (dry) type. (Note disappearance of intervertebral disc and fusion of bodies.)

Fig. 4.—Suboccipital tuberculosis. (Note characteristic posture of the head.) (After Wullstein.)

Fig. 5.—Caries sicca. (Note disappearance of disc and beginning fusion of bodies.) (After Wullstein.)

Fig. 6.—Granulation type peripheral form. (Note erosion of bodies, worm-eaten appearance, and large prevertebral abscess.)



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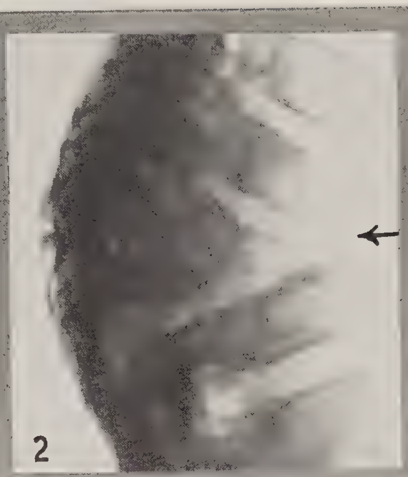

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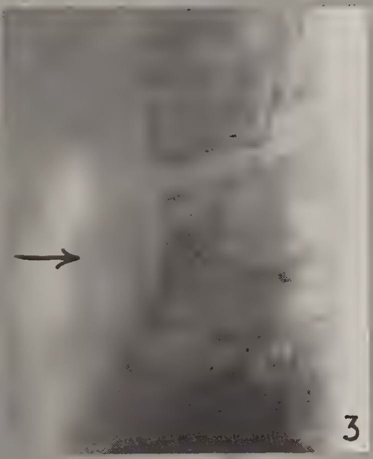

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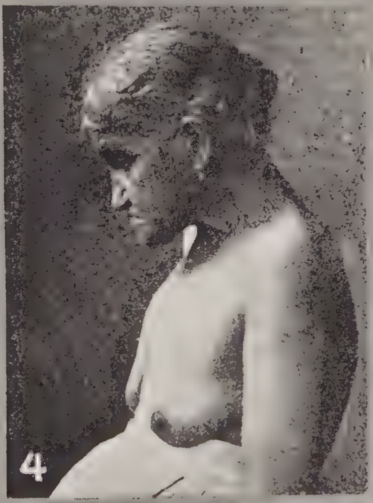

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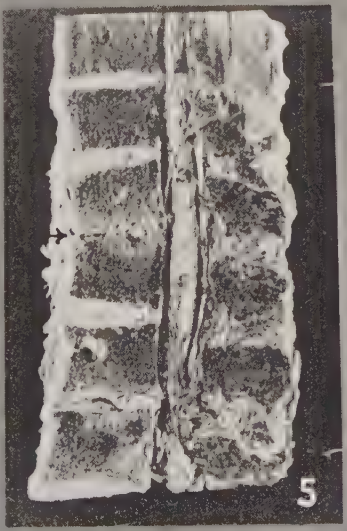

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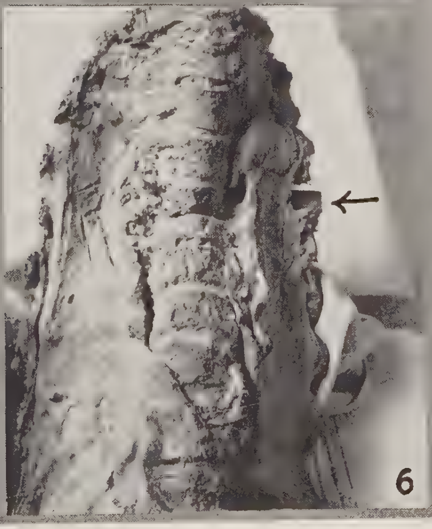

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PLATE LII

of the intervertebral discs and finally to their disappearance. When this occurs, contact between two or more bodies becomes established and the way is prepared for their subsequent fusion. Secondary tuberculosis develops in the neighboring vertebral bodies spreading from the central focus upward and downward under the anterior longitudinal ligament (Nichols[133]). At first the intervertebral disc is spared, but with the disease spreading to the adjacent vertebrae the cartilage is disattached from either side, becomes fibrillated, disintegrates and in the end disappears. Bone bridges from osteophytic formations are observed reaching from one vertebra to the other, though as a rule the fusion does not occur by formation of a heavy callus, but in a slow and insidious manner. When fusion finally does occur in the central type of spinal tuberculosis the collapse of the vertebrae under the stress of the superincumbent weight has already taken place and the characteristic posterior deformity known as ''gibbus'' has made its appearance.

b. The Anterior Peripheral Form.—The anterior portion of the vertebral body derives its blood supply from the intercostal and lumbar arteries reaching the body through the anterior longitudinal ligament. The infection spreads underneath the ligament and, as a rule, remains superficial. Not infrequently, however, it penetrates into the body and then becomes identical with the deep or central form which leads to the destruction of the vertebral body and to subsequent collapse. As the central form, this type also develops either as a fungus with all signs of tuberculous new formation, or as caseating form, producing superficial erosions at the anterior surface of the body especially around the blood vessels. The nutrient foramina appear enlarged and eroded, hence the French term, vermoulure, from the worm-eaten appearance of the anterior surface of the vertebra. Early diagnosis of this type is more difficult since the gibbus formation, pain, paralysis, etc., may be absent, due to the peculiar localization of the tuberculous focus (Loeffler[118]). This type, which starts from beneath the anterior longitudinal ligament, produces fungus granulations and macerates the anterior surface of the vertebral bodies, is, according to Krause,[110] the most common form of adult spinal tuberculosis. In its later stages it leads to destruction of the vertebral body and to collapse. In the course of the disease the destruction extends backward around the intervertebral disc, and most commonly reaches the posterior wall of the vertebral bodies penetrating into the spinal canal. Only when bodies and intervertebral discs have succumbed and are replaced by granulation tissue, deformation of the spine sets in.

c. The Epiphyseal Type (Plate LII, 3).—The epiphyseal type of spinal tuberculosis does not start from the intervertebral disc as was formerly believed, but it originates from portions of the vertebra adjacent to it, by way of the already described arteries entering the vertebral bodies posteriorly. The disc itself is very poor in vascularity, and it depends for its nutrition upon the fine arterioles coming from the anterior and posterior longitudinal ligaments. When these sources of supply are destroyed the intervertebral discs succumb to degeneration, so that their rôle must be considered more as a passive one.

When a disc has disappeared, the opposing surfaces of the neighboring vertebrae become adapted to each other without much displacement. The danger of anterior collapse of the vertebrae is consequently not so marked as in the case of primary central destruction of the vertebra. It is only when the caries extends farther forward to the anterior portions of the vertebra, that the tendency to anteroposterior deformity develops. How the tuberculous invasion gains the other side of the vertebral disc is still undetermined. That communicating arteries carry the infection seems unlikely, as no blood vessels are found in the discs. Such a secondary destruction and disappearance of the intervertebral discs in the course of vertebral disease is not peculiar to tuberculous infection. We find similar pathologic pictures in some malignancies, and also in spondylitis from typhoid, paratyphoid and typhus fever. The end-result of this form of caries of the bodies is complete fusion of the vertebral bodies, base to base, without or with little displacement.

d. Tuberculosis of the Neural Arches and Pedicles.—These structures are less suitable for the establishment of a tuberculous focus, since they consist mainly of compact bone. Formation of small sequestra and abscesses penetrating between the dorsal muscles to both sides of the spine has been observed. Compared with the involvement of the body the tuberculosis of the pedicles, of the articulations and neural arches, as well as of the transverse processes, is of rare occurrence. When arches or pedicles are involved on one side, an asymmetrical destruction of the vertebral substance results which causes a true lateral deformity. Not uncommonly this lateral deformity is combined with anteroposterior gibbus. The involvement of the articular processes of the vertebrae in the tuberculous process is extremely uncommon, except for the articulation between the 1st and 2nd cervical vertebrae. This latter localization develops a characteristic clinical picture known as suboccipital tuberculosis.

e. The Suboccipital Tuberculosis or Malum Vertebrale (Plate LII, 4).—Under this term is included tuberculosis located in the atlantooccipital, and in the atlantoodontoid articulation. It is a distinct clinical entity, known also under the name of Rust's[164] disease. The condition has been described and studied by Malgaigne and Lannelongue.[114]

Suboccipital tuberculosis is relatively rare; more common in children, seldom seen in advanced age (Richards[150]), its most frequent occurrence falls between the fifteenth and twenty-fifth years (in 46 per cent of all cases). The disease is not limited to one joint, but gradually involves all joints between occiput, atlas, and axis, leading to more or less destruction of the body substance. It develops as either an osseous or synovial form, producing erosion and caseous destruction of bone, detachment and subsequent disintegration of the joint cartilage and extension of the inflammatory process into the spinal canal. Not infrequently the odontoid process sequestrates and becomes separated from its base.

f. Tuberculosis of the Transverse Process.—Tuberculosis of the transverse process is extremely rare. B. H. Moore[130] reports a case of fracture of the transverse process of the 4th lumbar, due to tuberculosis.

3. Pathologic Types of Vertebral Tuberculosis

From the viewpoint of tissue reaction we find no departure in the different types from those essentials which make tuberculosis of the vertebrae a pathologic entity. The local hyperemia incident to the localization of tubercle material, the immediate tissue reaction with round cell infiltration and extravasation of leucocytes from the capillary system, the formation of primary miliary tubercles with epithelial cells and giant cells, the development of granulation tissue, are characteristic findings for each and all of the different forms. There is, however, a difference in the degree of the reaction of the tissue according to the virulence of the infection, according to the manner in which the inflammatory process extends, and according to the degree in which reparatory changes appear. In other words, the formation and extension of abscesses, the greater or lesser extent of bony destruction and correspondingly greater or lesser tendency to deformity, the ability to form bony callus or fibrous scars, while only secondary pathologic features, determine to a great measure the clinical course.

a. Caries Sicca: Dry Type of Tuberculosis (Plate LII, 5).—The new vascularization progresses more rapidly with the formation of granulation tissue, and the latter appears studded with miliary tubercles. The trabecular bone becomes rarified and melts down, but the virulence of the tuberculous invader becomes exhausted sooner than in other forms of tuberculosis and the reparatory changes more and more prevail. Then the granulation tissue becomes less vascular and is soon transformed into scar tissue leading to consolidation of the vertebral bodies.

b. The Granulation Type (Plate LII, 6).—This is the usual form. Tuberculous granulations appear without early tendency to retrogression. It comes to confluence of tubercules with caseation. In contrast to the dry form, here, the necrosis is not a molecular one but involves comparatively larger pieces of bone which become sequestrated. Caseation is followed by liquefaction of the necrotic area and the formation of tuberculous pus, walled off by a granulation tissue membrane which often appears thoroughly studded with minute tubercles. The contents of the cavity consist of tuberculous pus, caseous detritus, and fine particles of bone. In this type the tendency to progressive destruction is greater than in the former. The reparative process sets in later and usually a considerable amount of necrotic material is found accumulated in tuberculous cavities before the process of repair has become definitely established. This is the typical form for the central type of vertebral tuberculosis.

As the reparative process finally becomes established, the granulation tissue becomes more avascular and is transformed into scar tissue. Abscesses become walled off, their contents thickened; they become finally incrusted with lime salts and may calcify in the end.

c. The Type of the Tuberculous Necrotic Infarct.—This is an embolic process, and while not uncommon in tuberculosis of certain joints, especially in the knee, it is the exception in tuberculosis of the spine. In this form the tuberculous granulation tissue around the site of the embolus develops so rapidly that a large area of bone is being shut off from circulation. It becomes necrotic and a circumscribed wedge of bone is then separated to form a definite sequestrum. The latter, enveloped by granulation tissue, becomes eroded on its surface, and if small, may become completely absorbed. Larger sequestra become separated from their surroundings by a cover of granulation tissue. This type of tuberculosis is occasionally seen in the cervical spine, and it often involves several vertebral bodies at the same time.

d. Infiltrating or Progressive Type of Tuberculosis.—This type presents merely the secondary extension from a primary focus, which, producing an abscess under the anterior longitudinal ligament, goes on to erosion and infiltration of the anterior portion of the bodies of the adjacent vertebrae. From the granulation type it differs only by its mode of extension. The abscess accumulating under the anterior longitudinal ligament wanders downward, eroding on its way the anterior surface of the vertebra and honeycombing it.

4. Secondary Pathologic Changes

a. Deformity.—The characteristic deformity of tuberculosis of the vertebral bodies is anteroposterior kyphosis or gibbus formation, due to the forward collapse of one or more of the vertebral bodies. In the epiphyseal form a considerable amount of destruction may take place in adjacent parts of the vertebral bodies and the vertebral discs between them may become entirely absorbed without formation of an angulation. The destruction is here so uniform that it is not particularly affected by the superincumbent weight and no forward collapse of the vertebral body need occur. In this type the effect of body weight is rather that of telescoping or jamming together of the vertebral bodies. When the central part of the body is destroyed, however, as in the central, or in the peripheral form with more or less destruction of the anterior portion of the body, the resistance of the spinal column against weight bearing is overcome, and collapse with posterior angulation of the spine results. Against this impending deformity the bone reacts only very feebly. It is not until the process has become inactive that a halt is set to the deforming tendency. The angular deformity may attain the most extreme degrees and complete contact between the anterior surface of the vertebral bodies in neighboring sections may result.

(1) *The Mechanogenesis of Gibbus Deformity.*—It is very important to understand the mechanical forces active in the formation of the gibbus deformity. The degree of mobility in anteroposterior direction which normally exists, from vertebra to vertebra, in the dorsal and lumbar spine, has been thoroughly estab-

lished by kinesiologic investigatons (Fick, Virchow,[198] Novogrodsky,[135] and others). Albanese[1] comparing the anteroposterior mobility of the dorsal spine under normal conditions with that existing in destruction or operative removal of parts of the vertebral bodies, has come to the following interesting conclusions: to the natural range of forward flexion something more is added by the destruction of the vertebral bodies. This addition to the range of flexion Albanese provided in his experiments by the operative removal of a wedge from the vertebral body. The removal of this wedge at the level of the 5th and 6th dorsal produced an inflection of 18 to 20 degrees. The same wedge removed at the cervical spine caused an inflection of 8 to 9 degrees only, and in the lumbar spine of 11 to 12 degrees.

The ligamentous apparatus between the spinous apophyses opposes the collapse, and if this apparatus is destroyed or relaxed, the kyphosis becomes further accentuated by several degrees. When collapse occurs, there is a diastasis of the two contiguous articular processes which tend to separate in opposite directions. This diastasis also depends upon the degree of destruction of the vertebral bodies, and the greater the body weight, the greater the articular diastasis. While it is obvious that the factors leading to deformity do not entirely rest in the mechanics of joint motion or ligamentous check, yet these mechanical elements are of the greatest importance for the degree of angulation. Above all things they explain the difference in deforming tendency and in degree of angulation in the various sections of the spine.

(2) *Natural Check.*—In a number of cases we see that a natural check is put up against forward inclination of the body by the formation of proliferations or exostoses, or bony bridges spanned from vertebra to vertebra. Such bridges or synostoses may involve two neighboring vertebrae only, and often make their appearance even before a marked destructive change of the vertebral body is to be seen (Schipporeit[172]). As a rule, though, these natural provisions of defense prove insufficient. Cofield[46] in a study of one hundred consecutive cases of tuberculous spondylitis found ten in which hypertrophic bone bridges were present during the active stage of the disease, usually in individuals of over twenty years of age. Several of these cases had manifest pulmonary tuberculosis and active, progressing spinal caries. The new formed bone seems to form along the fibers of the anterior and lateral spinous ligaments, which are firmly attached to the hypertrophic formations. This suggests the possibilities that one has to deal with deposits within the ligaments, as a natural attempt to produce spinal fixation. Bone bridging was found also in several cases of the author's series (Plate LIII, 1, 2).

In some cases exostotic lamellae of bone extend from one vertebra to the other, completely encapsulating the disc and thereby produce a solid internal fixation of two adjacent vertebrae (Campbell[43]). It is perhaps interesting to recall in this connection that the so-called spondylose rhizomelique which is generally considered as a definite form of chronic deforming arthritis of the spine, is believed by some to be a superficial type of caries (Tubby[192]), accompanied by inflammatory arthritic changes. French authors especially believe that this type is a discrete tuberculous infection of the entire spinal column.

(3) *Scoliosis in Pott's Disease (Plate LIII, 3).*—Lateral curvature of the spine as a complication of Pott's disease is an old observation (Kirmisson[103]). American orthopedists have for a long time insisted upon the occurrence of this deformity in spinal tuberculosis. The lateral deviation is often accompanied by a certain amount of rotation of the spine imposing as a scoliotic deformity (Bartow,[17] Taylor[185, 186]). Lovett[123] insisted upon the importance of the lateral deviation as a diagnostic point in Pott's disease. According to him, lateral deviation is the rule in lumbar and low dorsal Pott's disease, but contrary to Bartow he thought it was not a rotatory but really an inclinatory movement of the trunk to one side. All cases reported by Kirmisson[103] and others (Phocas,[145] Lannelongue[114]), were of the lower dorsal and lumbar type. Sorrel and Talon[181] found lateral deviation in 29 per cent of the cases of Pott's disease, all but 1 per cent involving the last two dorsal and the first lumbar vertebrae. The tuberculous nature of this lateral curvature of the spine, if not immediately evident, usually reveals itself by the early rigidity of the spine due to muscle contracture (Ridlon[151]). In later stages, however, much of the lateral deviation is determined, not by muscle contracture alone, but also by rapid infiltration and diffusion of the tuberculous process (Vacchelli[193]). In the dorsal spine conditions are more favorable for anteroposterior deformity; lateral deviation, with the exception of the rare case of involvement of the arches, is a most uncommon occurrence. In the lumbar spine, however, conditions are favorable both for anterior and lateral deviations, and here the lateral deviations are comparatively frequent, especially if the tuberculous focus in the body is asymmetrically situated. The scoliosis always points with its concavity to the side of the lesion.

Tuberculous scoliosis usually appears early in the course of disease; only occasionally it develops in later stages. Differentiation against true scoliosis offers no difficulty. It is especially the scoliosis of the congenital type with its comparatively sharp angulation which must be considered.

b. Abscess Formation.—The destructive pathologic changes which lead to abscess formation have been described in general terms and it now remains to follow their development and extension. These abscesses are especially prone to leave their original site, to follow the forces of gravity, and finally to appear in remote regions of the body. The study of the migration of tuberculous abscesses from their original sites of development at the spine, to their appearance at the surface a considerable distance from the original site, is a study of the muscle and fascial planes along which these abscesses extend (Plate LIII, 4). They always take the route of least resistance. The principal routes of migration of abscesses originating from caries of the vertebral column are the following:

PLATE LIII

Fig. 1.—Osteophytic bone bridges in a case of active tuberculosis. (Note large paravertebral abscess.)

Fig. 2.—Lateral view of Fig. 1.

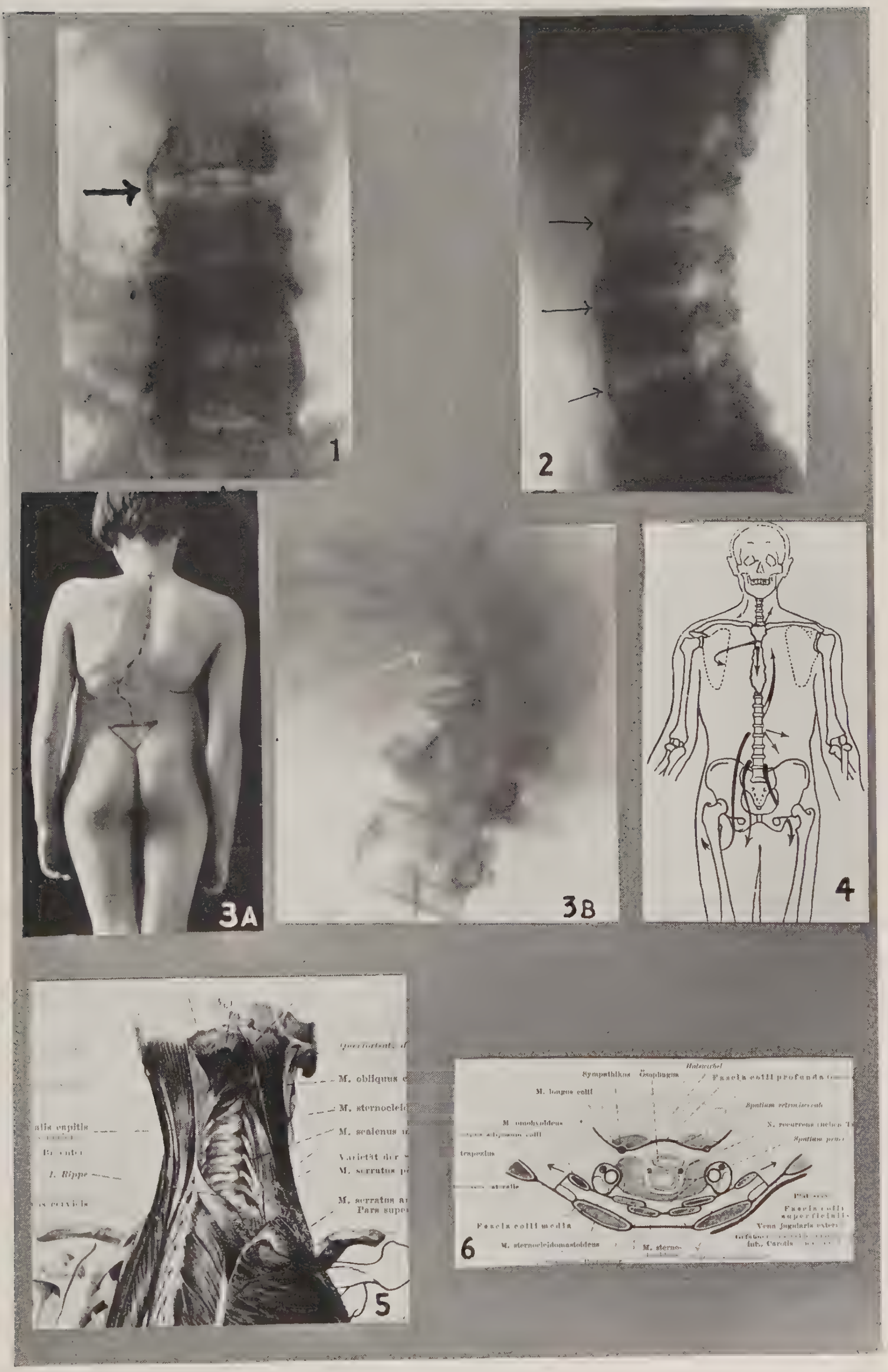
Fig. 3.—Scoliosis in Pott's disease. (Note sharp lateral angulation.)

Fig. 3A.—X-ray of case in Fig. 3.

Fig. 4.—Diagram of deflux of tuberculous abscesses in different regions. (After Vacchelli.)

Fig. 5.—Anatomy of cervical spine showing fascial compartment leading from transverse processes to lateral triangle of the neck. (After Braus.)

Fig. 6.—Diagram of cross-section through neck showing prevertebral, and visceral fasciae, vascular sheath, infrahyoid muscle fascia and vaginal fascia with trapezius and sternocleidomastoid in the latter. (After Braus.)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s cervicis
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Halswirbel
Sympathikus
Ösophagus
Fascia colli profunda
M. longus colli
Spatium retroviscerale
M. omohyoideus
N. recurrens (neben T
Spatium prae
trapezius
Fascia colli media
Fascia colli superficialis
Vena jugularis extern
Int. Carotis
M. sternocleidomastoideus
M. sterno-
6

PLATE LIII

(1) *Abscess Coming from the Suboccipital Region, from the 1st, 2nd and 3rd Cervical Vertebral Bodies.*

The determining factor for the downward deflux of these abscesses is the anatomic relation of the mighty muscle masses of the neck to the lateral processes of the vertebrae. Most of these muscles are attached to the posterior and some to the anterior tubercle of the transverse processes. The fascia covering these muscles (lateral extension of the prevertebral fascia [Prentiss, p.c.]) is spanned over the anterior surface of the vertebral bodies and from here covers the muscle attached to the costal element, the anterior tubercles of the transverse processes of the cervical spine (Plate LIII, 5). The abscess coming from the suboccipital region finds its way backward blocked by the great masses of the posterior muscles of the neck attached to the posterior tubercles of the transverse processes. Coming from the occiput and the posterior arc of the atlas, they may penetrate into the regions bounded by the posterior rectus muscles. As they tend to proceed more superficially, they encounter strong resistance in the tension of the posterior neck muscles, which explains the unusual tenseness of the abscesses and the rigidity and spasm of the muscles involved.

(2) *Abscesses coming from the anterior portions of the first three cervical vertebrae,* as well as those from the condyles of the occiput, may accumulate behind the anterior longitudinal ligament which is here more relaxed and allows the abscess to extend forward. In the loose areolar tissue underneath the prevertebral fascia, the abscess is now free to descend downward, or else it may gain the lateral aspect of the neck, entering the vascular compartment and appearing on the surface over the lateral triangle (Plate LIII, 6). More often, however, the abscess extends downward and forms a retropharyngeal abscess in the loose space between the pharynx and prevertebral fascia, a space very suitable for its extension and growth. It is then bounded above by the base of the skull, laterally by the vascular sheaths, while below the way is open to the posterior mediastinum (Plate LIII, 5). Protruding against the pharynx the abscess may obstruct deglutition and embarrass breathing (the so-called Angina Hippocratis). Occasionally such an abscess will burrow its way around the vascular sheath to the parotid, and, perforating the fascia of this gland, may reach the anterior margin of the sternocleidomastoid muscle. A rare and very grave complication is the extension backward of the abscess coming from the first three cervical vertebrae, its penetration into the vertebral bodies and its accumulation between the posterior wall of the vertebral bodies and the meninges.

The usual retropharyngeal abscess is caused more frequently by nontuberculous infection. Bokay (quoted by Townsend[190]) observed among two hundred and four cases seen between 1854 and 1880, seven cases due to caries of the spine, while one hundred and seventy-nine were pyogenetic, nine followed scarlet fever, one trauma, and seven developed from extension of pus from other sources.

(3) *Abscesses Coming from the Lower Cervical and Upper Dorsal Regions.*—When the lower cervical bodies are involved, the abscess, as a rule, erodes and destroys the anterior longitudinal ligament and makes for the posterior mediastinum. Only if there is some obstacle to its downward descent it is forced to appear in the supraclavicular fossa. The latter can be gained by two distinct routes: Either laterally along the scaleni or straight forward through the anterior longitudinal ligaments. Abscesses coming from the vertebral arches of this region usually follow the scaleni to the lateral triangle of the neck, and appear in the supraclavicular fossa. Those coming from the vertebral bodies at this level have already been described as accumulations of pus arranged behind the posterior pharyngeal wall, or penetrating into the spinal canal after erosion of the body. Again, accumulations of pus in the retropharyngeal space may become easily deflected by the visceral structures of the neck and their fascial compartments, and may secondarily follow a downward path along the vascular sheath, accumulating below the plexus and the triangle formed by the anterior and median scalenus muscles; they may then surround the subclavian artery and descend farther downward toward the axilla.

(4) *The Retromediastinal Abscess.*—The abscesses arising from the bodies of the lower cervical and upper dorsal vertebrae have some difficulty in making their downward descent for the anatomical reasons already mentioned (Plate LIV, 1). From the 2nd and 3rd dorsals downward, however, they usually find the way open to the posterior mediastinum, and then take an easy downward course in the space limited posteriorly by the vertebral column, laterally by the pleurae, and in front by the bronchial tree. This space, occupied by the thoracic aorta, the esophagus, vagus, the splanchnic nerve, the thoracic duct, the trachea, the veins, and the mediastinal lymph glands, is called the posterior mediastinal space. The relative elasticity of the latter easily allows the abscess to remain sessile and increase considerably in size (Plate LIV, 2). The pus accumulates behind the loosely attached esophagus, which, from the level of the 4th dorsal vertebra downward, becomes separated from the spinal column by taking a slightly forward and outward course toward the cardia. From this level on, pus may freely aggregate until the diaphragm is reached at the level of the 12th dorsal vertebra. Here, another obstacle arises to the descent. The diaphragm allows the passage of pus only between its crura medialia in front of the vertebral body; consequently, the abscess finding itself blocked, rises again and with increased pressure produces compression symptoms of the esophagus or trachea, or may even perforate into the pleura and pericardium (Plate LIV, 3).

In a case reported by Finckh[64] the abscess cavity had an enormous extent bulging against the pleural cavity, so that the upper lobe of the right lung was compressed to a flat fan-shaped formation, and was completely excluded from respiration. Without perforating into the pleural cavity this abscess extended around the inner thoracic wall on the right to the sternoclavicular junction finding an outlet through the anterior thoracic wall.

PLATE LIV

Fig. 1.—Paravertebral abscess extending laterally along ribs. (Note costovertebral destruction with inclination of body.)

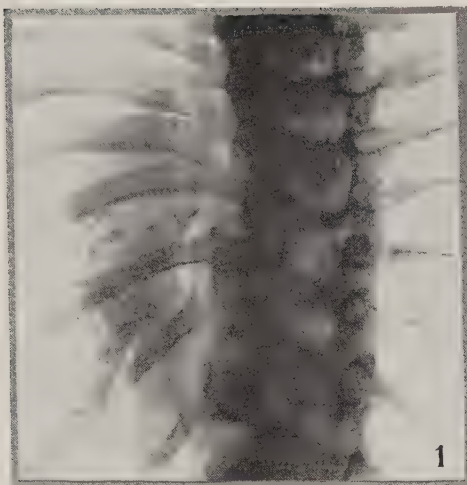
Fig. 2.—Diagram of retromediastinal space. (After Vacchelli.)

Fig. 3.—Retromediastinal abscess squatting on the diaphragm.

Fig. 4.—Anatomy of the diaphragm showing internal crura as passageway for subdiaphragmatic abscess. (After Braus.)

Fig. 5.—Psoas abscess from caries of 2nd, 3rd, and 4th lumbar vertebrae. (Note bone bridges between vertebrae.) Sinus tract injected.

Fig. 6.—Presacral abscess from sacrolumbar tuberculosis. (Double spinal focus in this patient.)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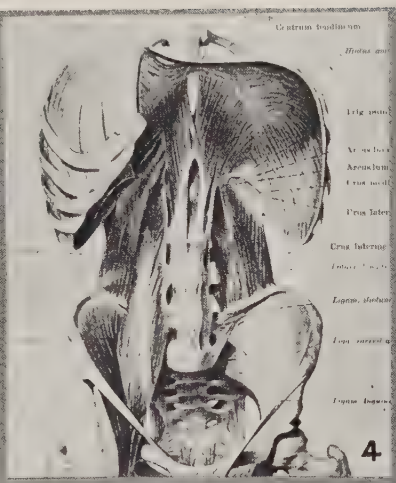
Centrum tendineum
Hiatus aor
Arcus lum
Crus med
Crus later
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Ligam. inguina
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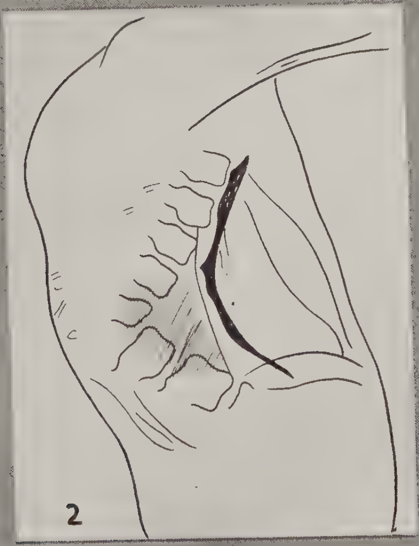
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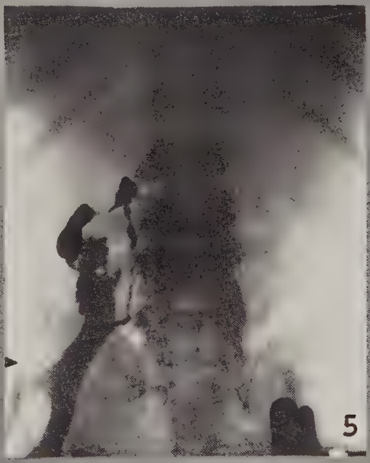
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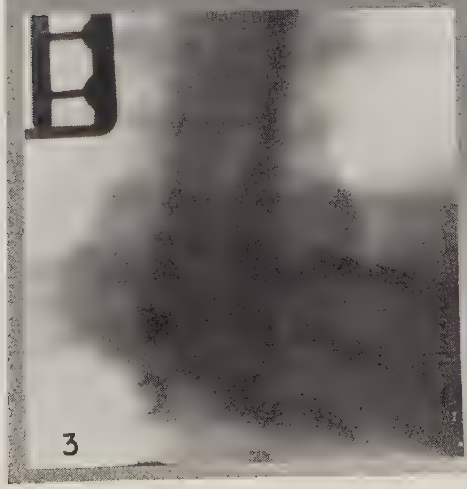
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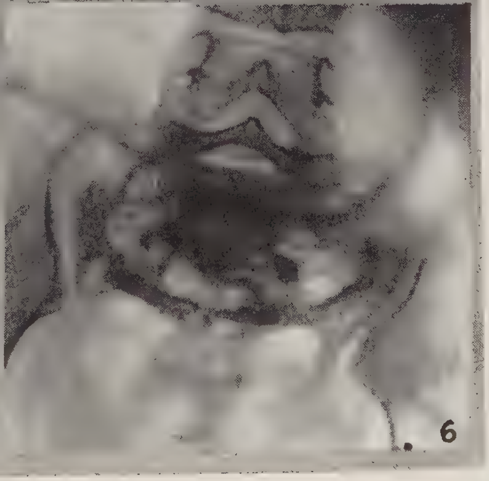
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PLATE LIV

One often sees these abscesses extend laterally toward the transverse process, or the costovertebral articulations. From here they reach the intervertebral or intercostal spaces and may appear as cold abscesses between the posterior portions of the ribs. The intimate connection of the anterior longitudinal ligament with the costovertebral articulation explains the deflection of the vertebral abscesses toward the intervertebral and intercostal spaces. With its strong fibers the anterior longitudinal ligament resists the protrusion of the abscess toward the pleural cavity to a considerable extent. At autopsy one sees distinct erosions of the anterior portions of the vertebrae, of the pedicles, and of the laminae, indicating the amount of pressure which is exerted upon the abscess by the anterior longitudinal ligament. With the increased accumulation of pus, however, it finally comes to perforation of the ligament and to invasion into the retromediastinal space. As the abscesses reach the intercostal spaces and appear as cold abscesses over the posterior portions of the rib, differentiation from tuberculosis of the rib becomes difficult.

(5) *The Posterior Extension of the Prevertebral Abscesses.*—In a number of cases the abscess situated underneath the anterior longitudinal ligament corrodes the surface of the vertebral body and finally penetrates through it into the spinal canal. In other instances this communication is established by the extension of the abscess around the bodies and pedicles. The result is a pressure upon the spinal cord, and the attending compression symptoms constitute the gravest complication of the vertebral tuberculosis.

(6) *Subdiaphragmatic Extension (Plate LIV, 4).*—The narrow space between the internal crura of the diaphragm is a sufficiently effective barrier against penetration into the subdiaphragmatic space in all but a small minority of cases. After having found its way through the diaphragm the abscess progresses downward in the fascial sheath which forms the compartment for the psoas muscle. The abscesses coming from the lumbar spine extend either between the iliac fascia and the iliopsoas muscle, or between fascia and peritoneum in the cellular subperitoneal space (Plate LV, 1). We accordingly distinguish between subfascial and subperitoneal abscesses.

The most common route of extension is that between the iliopsoas muscle and its fascia (Plate LIV, 5). From here the abscess gradually finds its way into the lacuna musculorum, and then downward to the lesser trochanter, following the run of the psoas muscle. Abscesses coming from the os ilei or from the 5th lumbar vertebra, following the course of the iliolumbar artery, often penetrate behind the psoas muscle and then also follow the ordinary run of the psoas abscess. As they descend below Poupart's ligament they appear at the inner side of the thigh, often forming a bilocular abscess, with one portion above and one below Poupart's ligament.

The second subdiaphragmatic route is the suprafascial or subperitoneal. Here the abscess lies above the fascia of the iliopsoas muscle, and between it and the peritoneum. The abscess finding its way easily in the upper tract where the fascia is thin and supple, encounters greater difficulties in the aponeurotic sheath of this muscle, and, penetrating through it, it gains the subperitoneal space. So, an abscess often begins as a subfascial abscess to become retroperitoneal further downward. In other instances the subperitoneal abscess may arise directly by perforation from the body of the lumbar vertebra through the anterior longitudinal ligament. These retroperitoneal abscesses follow the course of the external iliac vessels which form the inner border of the iliac fossa. They then appear in the lacuna vasorum, and from here gain the inner aspect of the thigh. Since the iliac fascia is continuous with the sheath of the pectineus muscle, this muscle also becomes invaded and the abscess appears within this muscle at the inner side of the thigh. Clinically, the abscess coming through the crural canal by way of the lacuna vasorum is distinguished from that coming through the lacuna musculorum (subfascial psoas abscess), in that the latter is situated in front of the femoral vessels and therefore the beat of the femoral artery cannot be made out, while those coming medially through the lacuna vasorum leave the artery laterally and the beat of this vessel can be palpated. Of the two types the retroperitoneal is much more serious because the opportunity for uncontrollable extension of the abscess throughout the pelvis is very great. Abscesses of this kind are often observed in tuberculosis of the 5th lumbar and of the os ilei as well as in sacroiliac tuberculosis. They are extremely difficult to drain and, once becoming infected, they give rise to severe sepsis to which the patient very often succumbs. The retroperitoneal abscess may compress the ureter or the bladder, or perforate into the latter. It may also surround the intrapelvic organs, reach the ischiorectal space and develop into an ischiorectal abscess (Plate LIV, 6). It may further extend laterally, following the course of the pyriform muscle through the lesser pelvis and extend from here to the greater sciatic notch. Burrowing its way between gluteus maximus and medius muscles, it may then follow the run of the great sciatic nerve in the posterior compartment of the thigh. It may also extend forward and appear at the surface between the anterior border of the tensor fascia and rectus femoris muscle.

(7) *The Lumbar Abscess (Plate LV, 2).*—Abscesses coming from the lumbar region or the region of the sacroiliac articulation may extend straight laterally and find an outlet over Petit's triangle (Loeffler[117]). This trigon is marked by a field in which the external and internal obliques are absent, so that the posterior abdominal wall is formed by the deep layers of the lumbodorsal fascia only. It is bounded anteriorly by the external oblique muscle, posteriorly by the latissimus dorsi, and below by the bony rim of the pelvis (Plate LV, 3). Pus may reach this triangle after perforation of the fascia of the psoas muscle and penetrate around the outer border of the quadratus lumborum.

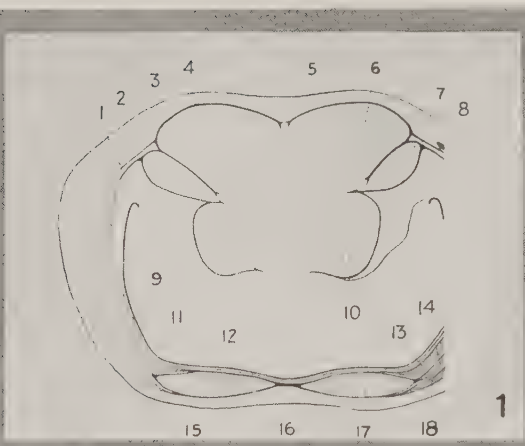
(8) *Abscesses Coming from the Vertebral Arches and the Spinous Processes.*—These abscesses may penetrate into the muscular layers and appear close to the midline in the back. If they arise from the transverse processes they show a different route according to the level. In the cervical segments the abscesses strictly follow the course of the scaleni in a manner already described. In

PLATE LV

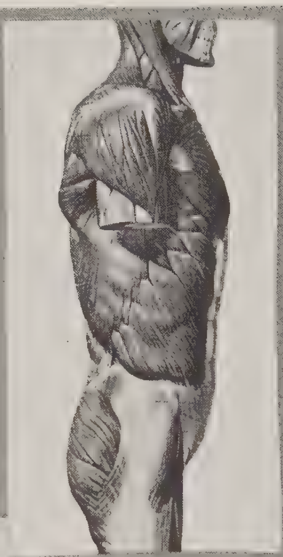
Fig. 1.—Anatomic drawing showing fascial relation of the iliopsoas muscle and peritoneum. (After Braus.)

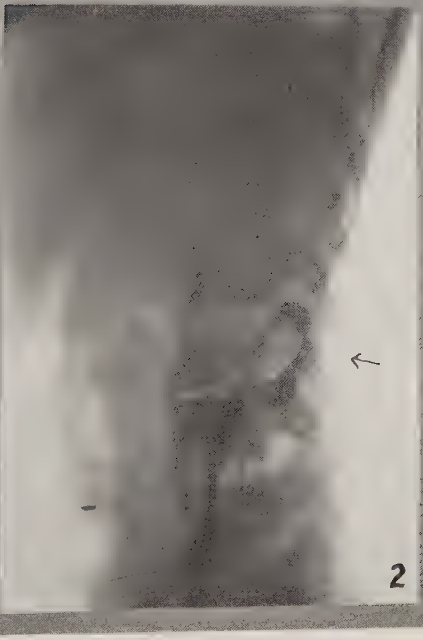
Fig. 2.—Lumbar abscess opening through Petit's triangle. (After Braus.)

Fig. 4.—Drawing showing operative findings at laminectomy for cord compression. (Note granulation tissue constricting and narrowing of the cord; note also caseation in three of the laminae.)



1. Subperitonaeales Fett. 2. M. obliquus abd. internus. 3. Tiefes Blatt der Fascia lumbodorsalis. 4. Fascia lumbodorsalis, oberflächl. Blatt. 5 and 6. Tiefe Rückenmuskeln. 5. Transversospinales system, 6. Sakrospinales system. 7. M. obliquus abd. internus. 8. M. quadratus lumborum. 9. Fascia lumbalis. 10. M. psoas. 11. Peritoneum. 12. Fascia transvers. 13. M. transversus. 14. M. obliquus abd. internus. 15. Vagina recti. 16. Linea alba. 17. M.rectus abd. 18. M. obliquus abd. externus.





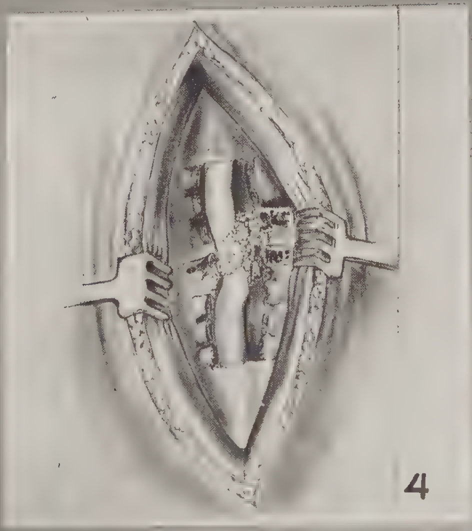


PLATE LV

the dorsal segment the abscesses circle the long muscles of the spine and appear as prevertebral abscesses at the lateral border of the erector spinae mass. In the lumbar spine a paravertebral abscess is rare owing to the powerful muscles and the great density of the lumbodorsal aponeurosis. In the majority of cases such abscesses find a deflux into the abdominal cavity, following the course of the psoas muscle, or, they find their way around the lateral border of the quadratus lumborum and finally reach Petit's triangle as the least resistant point of the abdominal wall.

c. Cord Compression.—Among the secondary pathologic changes in tuberculosis of the spine, compression of the spinal cord is second in importance only to abscess formation.

(1) *Pathology.*—It is now generally assumed that the compression of the cord is not exerted directly by bony pressure, but by pressure of inflammatory products which reach the spinal canal. Such an extension into the spinal canal may come either direct from the vertebral body or from a mediastinal or prevertebral abscess which perforates the body of the vertebra and reaches the extradural space. Next to penetrating abscesses, the pressure exerted by inflammatory granulation tissue is of importance. Only exceptionally compression is due to actual bone pressure.

Indirectly a damage may be caused to the cord by compression of the costal arteries which supply the cord, so that by thrombotic occlusion ischemia and degenerative changes are produced in the cord. It has been demonstrated by Kahler[100] that the lymphatic system within the spinal cord also exercises a very sensitive regulatory activity so that even in mild compression of the lymphatic channels in the arachnoid space, a lymphatic stasis of the spinal cord may take place which ultimately may lead to paralytic symptoms.

In order to fully understand the mechanical effect of compression, one must recognize the soft and elastic nature of the pressure-producing tissues (Plate LV, 4); hence the possibility of regeneration when the pressure ceases, and the frequent disappearance of compression symptoms spontaneously or under appropriate treatment.

(2) *Development.*—Spinal compression usually occurs in a gradual and insidious way in keeping with the slow collapse of the spine. On the other hand, cases of rather sudden appearance of cord compression, although the exception, are not extremely rare. It happens occasionally that a carious vertebra after slight trauma, suddenly collapses, allowing the posterior wall of the vertebral body to project sharply against the spinal canal and to exert an acute and instantaneous compression upon the cord. Cases which developed so rapidly that the turn from the spastic to the flaccid type of paralysis took place within a few days or even a few hours were repeatedly observed by the writer. As a rule, however, it is elastic and not rigid compression that produces the cord symptoms.

In order that the inflammatory products may gain the interior of the canal, the perforation of the posterior longitudinal ligament is necessary. When this has occurred, pus or granulation tissue may now extend up- and downward within the canal, sometimes for a considerable distance. Later the dura itself becomes involved, and a pachymeningitis externa tuberculosa develops with edematous swelling, thickening, etc.

(3) *Cord Changes.*—The pathologic changes of the spinal cord have been carefully investigated by Schmaus.[173] He found that compression of the meninges produces blockage of the lymphatic flow, and indirectly edema of the arachnoid, and leptomeningitis, with functional disturbances. If the edema exists for a long time, it comes to softening processes and reactive inflammation which finally ends up in sclerosis of the cord. One finds groups of old axial cylinders having lost their myelin sheaths partly or completely, and in many places the hyperplastic edematous stroma of neuroglia with fibrous interstitial degeneration of the cord as the end-result. Only rarely true tuberculous masses are found in the cord, but it is not uncommon to see specific inflammatory changes extend from the bony focus into the substances of the medulla.

In a similar way the spinal roots may become involved by being surrounded by inflammatory tissue, they also become edematous and infiltrated (perineuritis), and undergo subsequent atrophy and fibrous degeneration.

5. Reparative Changes in Tuberculous Spondylitis

a. Natural Fusion.—

(1) *Bodies.*—Nature aims at bony fusion of the vertebral body, thereby limiting the tuberculous process. This fusion is either total or partial, and extends not only to the bodies themselves but also often includes the transverse processes and arches. Occasionally this fusion is assisted by the production of osteophytic growth extending between the diseased and the neighboring vertebrae, and seen most extensively underneath the anterior longitudinal ligament. There is no direct relation between the degree of repair and the amount of morbid destruction. In some cases the bony fusion develops simultaneously with the persistence of carious foci (Plate LIII, 1, 2).

(2) *Posterior Fusion.*—In the majority of cases, there appears, together with the repair of the bodies in front, also fusion of the posterior portions of the spine: ankylosis of the intervertebral articulations as well as fusion between the laminae, the transverse, and sometimes even the spinous processes. While bony fusion between vertebral bodies is the usual event in children, it is not so in adults. Here the reparative process usually terminates with fibrous union. It appears, also, that reparative changes such as ossifying periostitis between the spinous processes or true ankylosis between the articular processes can develop without any signs of repair in the anterior portion, so that a fusion in the posterior portion is found independent of the pathologic status of the vertebral bodies (Albanese[1]). This is of greatest importance in estimating the value of operative fusion of the posterior column of the spine. While it is not proved that such posterior ankylosis may actually inhibit the formation

PLATE LVI

Figs. 1-2.—Patient (C.Y.) in 1925 destruction of 10th, 11th, and 12th dorsal vertebrae. (Anteroposterior and lateral views.)

Figs. 3-4.—Same patient one year later. (Note progress of repair—beginning blocking.)

Figs. 5-6.—Same patient two years later with complete bone blockage.

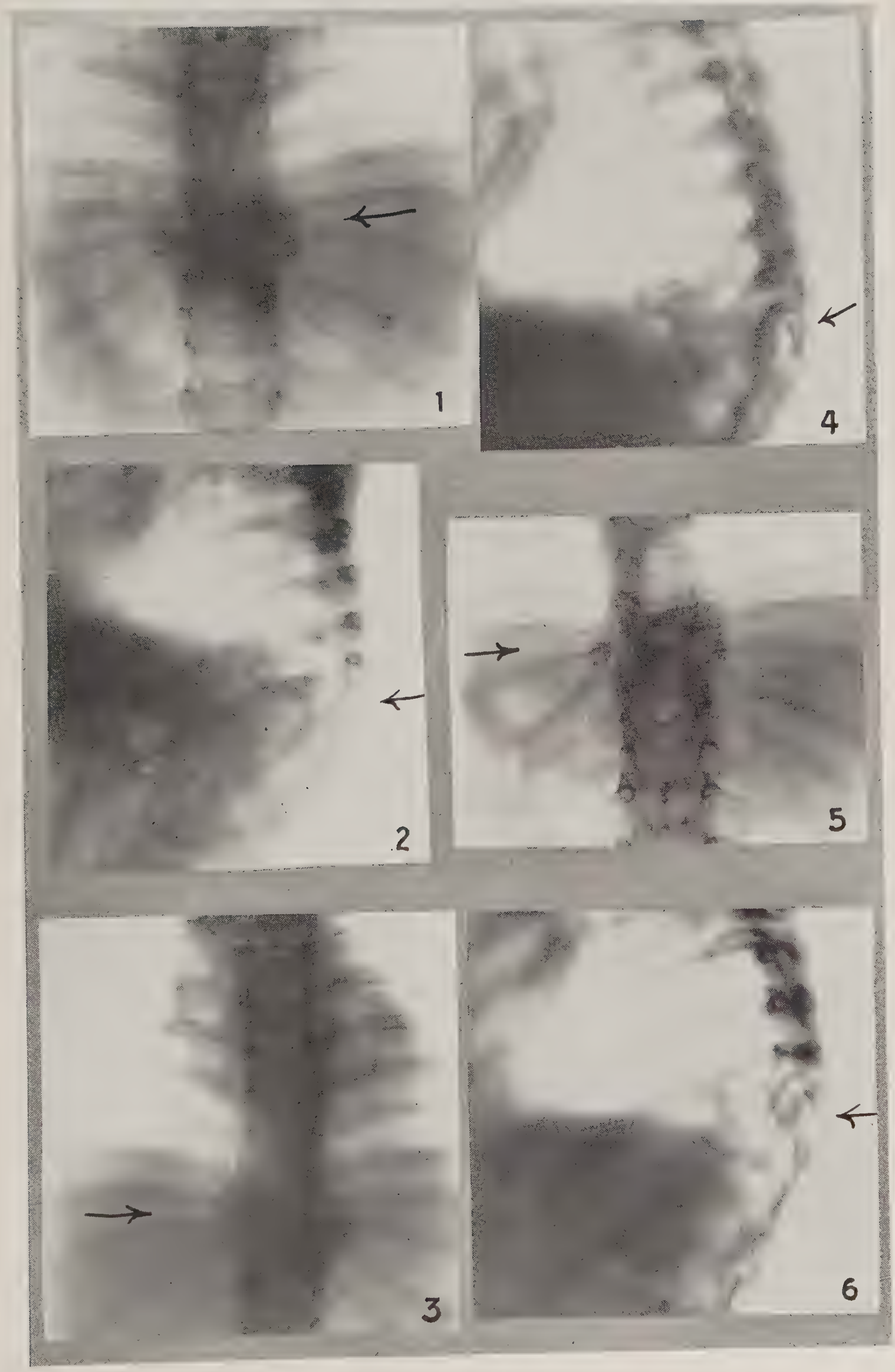


PLATE LVI

of the gibbus, yet there is evidence to show that the process of ossification and fusion may effectively limit the kyphotic curve, and thereby aid materially in the recovery. The natural fusion of the posterior portions of the vertebra is to be regarded as responsive osteogenetic reaction to the stimulus of the tuberculous foci within the body.

The formation of the gibbus, or the posterior deformity, must be viewed as a phenomenon of repair. As we follow the course of the disease in the x-ray picture, we see that in children the repair of the vertebrae appears as complete bony fusion of one or two of the involved segments (Plate LVI, 1-6). In adults this bony fusion is the exception. Here, healing occurs by granulation tissue, which is finally transformed into healthy scar and connective tissue, consolidating the spine by fibrous adhesions. Mention has also been made of the bony bridges uniting the affected vertebrae, which often simulate osteoarthritis. They are easily demonstrable in the x-ray picture. In accordance with a previous statement that destructive and reparative processes are often found to run parallel, we find that fibrous scar masses not infrequently include caseous material or sequestra. Such foci remain latent for a long period of time, but always retain their infectious character, giving rise to recrudescence of the process in later years.

b. Blockage.—The deforming process finds a natural check in the formation of a bony block formed by the collapsed vertebral bodies. Because of the fibrous union in healed adult tuberculosis of the spine, this blockage is never so definite and absolute as it is in children (Plate LVI). In the mechanical effect of certain operations of the spine this phenomenon of blockage becomes of great significance (see Palliative Operations).

c. Reparative Changes of the Tuberculous Abscess.—Small abscesses become completely absorbed, larger ones are walled off by connective tissue derived from the pyogenic membrane and gradually become sterile. They are then transformed either into a mucous fluid, or become incrustated with lime salts until they appear in the x-ray picture as heavy shadows simulating stones. A certain percentage of abscesses (30 per cent) become clinically manifest as superficial cold abscesses. They will be discussed with the Clinical Symptoms.

V. SYMPTOMS

1. General Signs

Symptoms referable to the general condition of the patient precede the local manifestations sometimes for a long period of time. In the interest of early diagnosis and better and more efficient treatment, the closest attention should be given to these early systemic manifestations, namely: loss of weight and appetite, anemia, feeling of tiredness, listlessness, change in disposition, restless sleep, and occasional afternoon temperature.

2. Local Symptoms

a. Pain.—

(1) *Spontaneous, Referred.*—Vague, ill-defined pains are occasionally forerunners of more definite and localized signs, especially in adult patients. Complaint is made of pain in abdomen, chest or head, without other symptoms pointing to a definite level of the spine.

More frequent is pain referred along intercostal and intersegmental routes; it is a characteristic and common symptom in adult spinal tuberculosis. Here belong the girdle pain, the iliac pain, pain simulating gastric crisis, the pain referred to the inguinal region or to the gall bladder, or the pain in the precordial region. The common distribution is as follows: in cervical disease pain is referred to occiput and arm; in dorsal disease pain is referred to the sternum or appears as intercostal neuralgia; in dorsolumbar disease there is pain in the epigastrium and girdle pain; and in the lumbar disease there is pain referred to hips and legs.

(2) *Spontaneous Local Pain.*—Local, spontaneous pain at the seat of disease is complained of very frequently in adults, as one of the earliest signs of spinal tuberculosis. In children this type of pain is manifested by night cries, similar, though not so frequent, as in tuberculosis of the hip joint. Night cries are more common in younger children, and more frequent, again, in cervical and dorsal, than in lumbar disease. A sudden relaxation, during sleep, of the reflex rigidity of the dorsal musculature, which safeguards the spine against painful intervertebral movement, is responsible for this phenomenon. (Table VII.)

(3) *Pain, Elicited.*—The tuberculous spine is sensitive against jarring and sudden concussion. Pain is often complained of after sneezing, coughing, or forced expiratory movement, and such acts are carefully avoided. Pain is also elicited by direct pressure over the spinous processes. The symptom of pain elicited by direct pressure or by jarring or concussion, when found, is of great diagnostic value. On the other hand, because of the inconstancy of this sign, its abscence should not influence the diagnosis. On the whole, pain, referred or local, spontaneous or elicited, is a rather inconstant symptom, especially in children; it is more common in adult spinal tuberculosis.

b. Rigidity.—Rigidity of the spine is due partly to reflex contracture of the musculature of the back and partly to volitional contraction, as an attitudinal feature assumed by the patient to save the affected portions of the spine from motion which would be harmful. The greater the natural mobility of the particular section of the spine the more carefully it must be protected. The freest motion is centered in the lumbodorsal section and in the cervical spine.

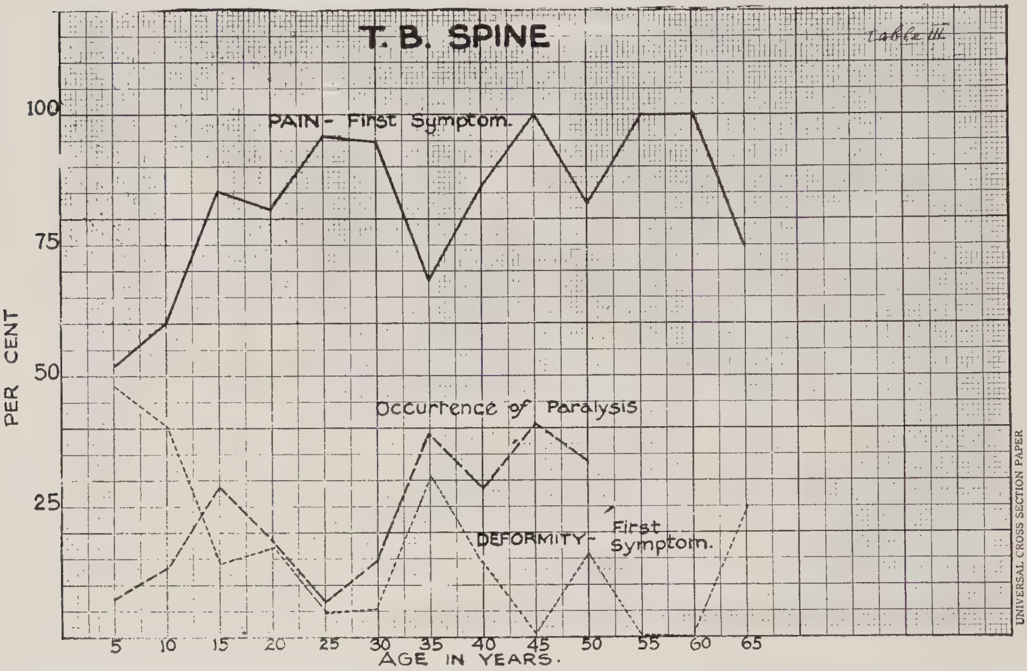
(1) *Attitudes.*—In the endeavor to immobilize the spine by active and voluntary muscle control against any movement, the patient assumes a certain peculiar and characteristic attitude. In walking as well as in standing he constantly seeks and applies means of support for the body.

In tuberculosis of the atlantooccipital articulation and in the cervical spondylitis, he lays his hands upon both cheeks supporting the occiput and relieving the spine, thereby, from the weight of the head.

In high dorsal spondylitis he uses his hands to brace himself against near-by objects, relieving the spine of the weight of the head and of the upper portion of the trunk.

In the lower dorsal and lumbar disease the patient supports himself by placing both hands upon the anterior surface of the thighs or the hips.

TABLE VII



In forward bending the spine is held so rigid that all flexion movement is left to the hip joint. As the patient straightens out from a crouched position he carefully climbs up with his hands placed upon the thighs. The patient walks in the same guarded and careful manner which gives his gait a characteristic inflexible puppet-like appearance.

(2) *Reflex Contracture.*—Reflex contracture of the spine is superimposed upon voluntary contractures and both produce a most effective safeguard against movement in the diseased portion. When contracture of the muscles relaxes as in deep sleep, and the muscles are off their guard, so to speak, movement occurs and produces sudden pain manifested as night cries.

Rigidity is much more frequent, but it, too, is not an entirely constant early sign. Valtancoli[196] finds it in 73 per cent.

c. Gait and Posture (Plate LVII, 1, 2, 3, 4, 5).—The gait, due to the muscle contraction, appears guarded and deliberate. The patient avoids all violent contact with surrounding objects, feeling his way carefully with his hands, and using every opportunity to support himself upon near-by objects. His steps are short and he often resorts to toe walking to lessen the jar and shock upon the spine. All violent exercises such as jumping or running are avoided. When picking up objects from the floor he lets himself down very carefully, bending his hips and knees, and always keeping the trunk erect. When he rises he climbs with his hands upon his thighs with the trunk also in perpendicular position.

Cases of cervical disease are seen with the head held in extreme hyperextension and with the chin drawn up; in other cases it is held in flexion, but, in either event, it is held rigid and immovable.

A peculiarity of the gait is often created by the presence of a psoas abscess, resulting in flexion contracture of the hip joint. In this case the body is thrown forward with the affected leg flexed at knee and hip, and the patient walks upon the toes.

In dorsal disease the favored attitude in standing is with the body flexed forward. In lumbar disease the attitude is characterized by hyperextension. In asymmetrical cervical disease the head may assume a position of torticollis. Changes in attitude and gait are frequent symptoms and appear comparatively early, always associated with rigidity and muscle contracture.

d. Deformity (Plate LVIII, 1, 2, 3, 4, 5).—

(1) *Gibbus.*—Deformity is a frequent, although by no means a universal symptom. In children it is often an early symptom; in adults it usually occurs later, other, subjective, symptoms preceding the deformity.

Anteroposterior deformity or gibbus develops slowly and insidiously, and in adults it is usually ushered in by a period of pain lasting over weeks or months. In exceptional cases, especially in children, one sees the deformity develop rapidly upon a more or less sudden collapse of the vertebrae.

The deformity in Pott's disease is usually distinct and angular in shape; it is seldom an arcuar or rounded deformity like that seen in rickets. Furthermore, this angular deformity is distinguished from the rachitic gibbus by its rigidity; it cannot be made to flatten out as the patient, lying prone, has his legs and pelvis lifted off the table; whereas, in a rachitic curve under those conditions, it flattens out and becomes effaced. Lateral deviation is not uncommon in Pott's disease. It is most frequent in the lower dorsal and lumbar spine, and is due to asymmetrical distribution of the tuberculous destruction within the body of the vertebra. There is, as a rule, no rotation in contrast with true lateral curvature as seen in structural scoliosis.

(2) *Compensatory Curves (Plate LVIII, 6).*—The anteroposterior deflection of the body at the site of the tuberculous lesion produces compensatory curves in the adjacent portions of the spine. It must be expected that, under the

PLATE LVII

Fig. 1.—Attitude in cervical disease.

Fig. 2.—Attitude in cervicodorsal disease. (After Henle.)

Fig. 3.—Attitude in lower dorsal disease. (After Henle.)

Fig. 4.—Attitude in lumbar disease. (After Henle.)

Fig. 5.—Lateral deformity in lumbar disease (After Henle.)

Fig. 6.—Deformity of thorax in upper dorsal disease. (After Lannelongue.)

Fig. 7.—Deformity of thorax in dorsolumbar disease. (After Lannelongue.)

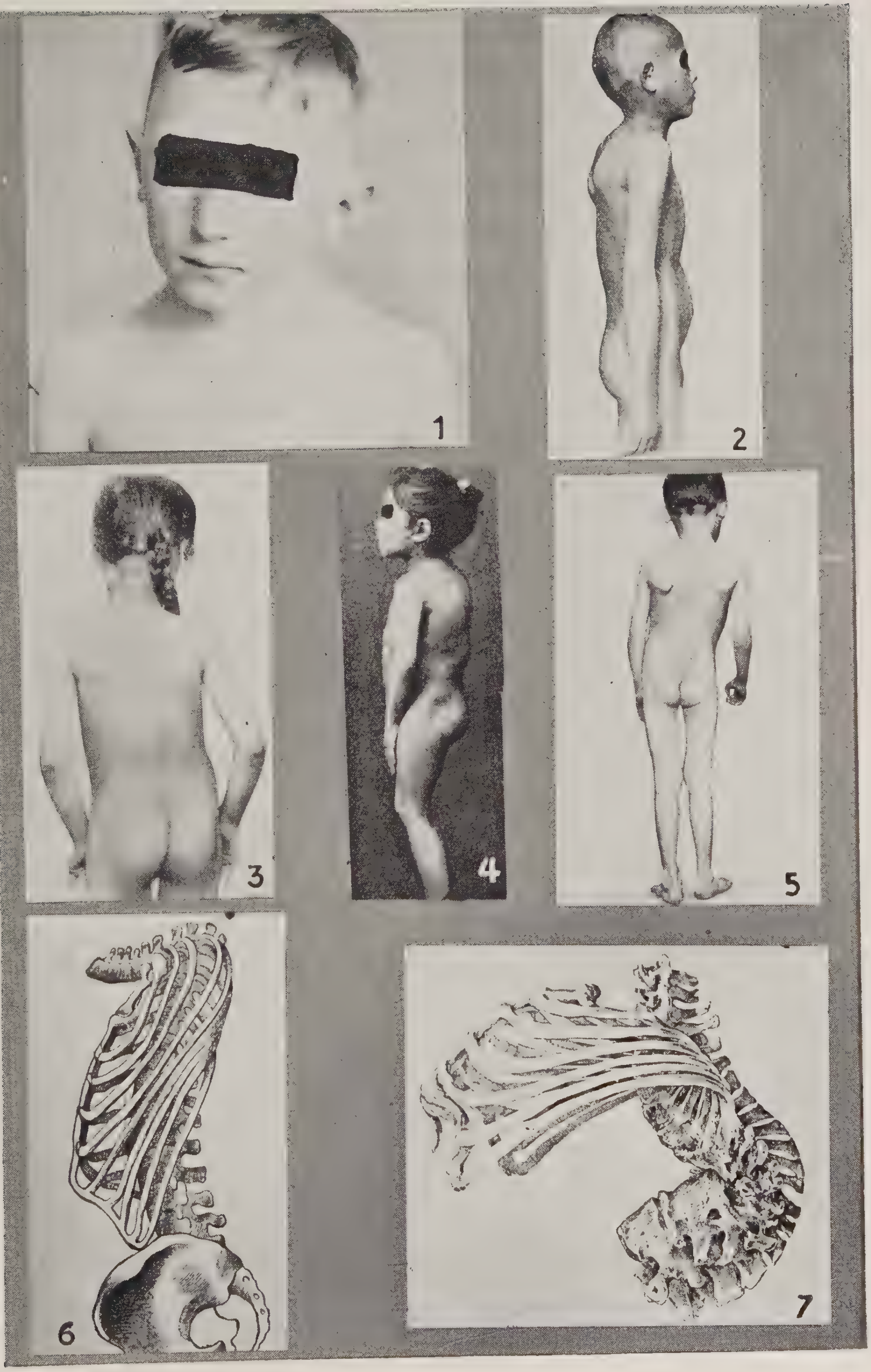


PLATE LVII

PLATE LVIII

Fig. 1.—Cervical gibbus.

Fig. 2.—Upper dorsal gibbus.

Fig. 3.—Mid-dorsal gibbus.

Fig. 4.—Lower dorsal gibbus.

Fig. 5.—Lumbar gibbus.

Fig. 6.—Compensatory curves above and below gibbus.

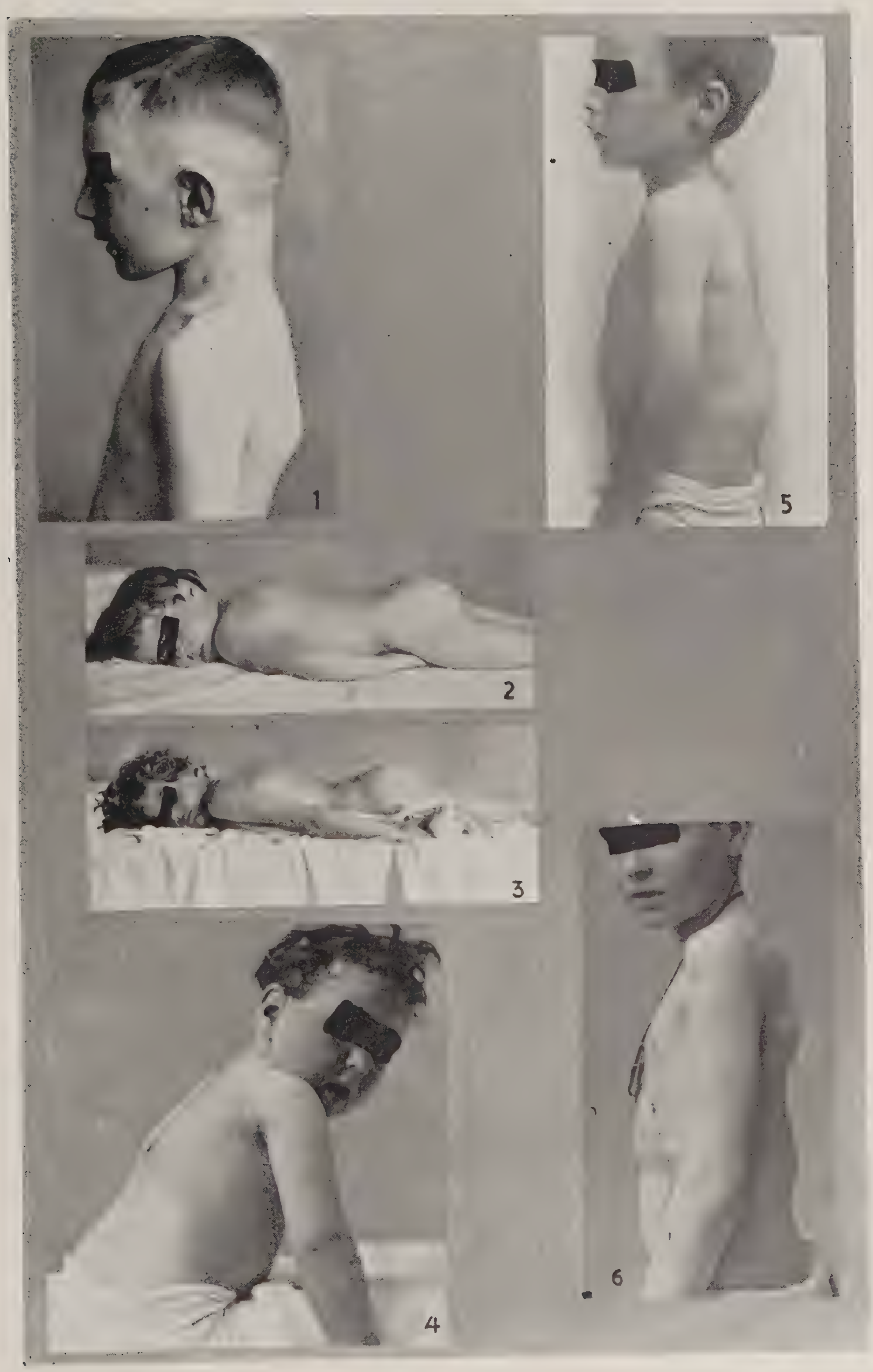


PLATE LVIII

laws of gravity, the body which becomes deflected from its proper direction must return to proper relations to the line of gravity in order to maintain its balance. So we see above and below the gibbus curves produced by active muscle contracture. These compensatory curves involve a good deal of adaptation between the ligamentous apparatus of the posterior, and that of the anterior portions of the spinal column, as well as of the intervertebral discs. The fullest use is made of the ability of the spine to develop compensatory or lordotic curves above and below the site of the original gibbus. The compensatory effect of the adjacent portions becomes more evident in the dorsal section where the superincumbent dorsocervical and the underlying dorsolumbar sections are used for compensation by accentuating their normal physiologic lordosis. Owing to this fact the kyphotic curve appears more flat and the gibbus becomes actually shortened as the more pliable upper and lower ends of the kyphosis are drawn into the compensatory curves.

(3) *Statistics.*—Anteroposterior deformity is found in about 68 per cent of all cases (Valtancoli). According to this author the apex of the curve in dorsal disease is most frequently at the 7th dorsal, next the 12th, and then the 9th dorsal. In lumbar disease the apex of the curve is most frequently at the level of the 2nd lumbar vertebra, and, in cervical disease, at the level of the 7th cervical.

The writer's statistics show anteroposterior deformity present in 65 per cent of his cases, and absent in 35 per cent; moderate in 32 per cent; marked in 24 per cent, and extreme in 9 per cent of all cases.

e. Thoracic Changes.—

(1) *Skeletal.*—Thoracic changes are especially marked if the disease is situated in the upper half of the dorsal spine. The kyphotic forward flexion of the upper dorsal spine causes the ribs to take a sharp downward slant and the thorax appears flattened anteriorly. The sternum protrudes more at its lower end. The lower ribs being attached to the part of the dorsal spine below the gibbus show much less change of direction. The result of the deformation is that the anteroposterior diameter appears shorter, the thoracic cage is flattened from side to side, and the vertical diameter of the thorax is lengthened (Plate LVII, 6). If, on the other hand, the gibbus occupies the lower dorsal spine or the lumbar spine, then the descent of the ribs is not materially changed and they maintain a more horizontal plane. The thoracic cage appears lengthened in its anteroposterior diameter, is flattened from side to side, but is shortened in its vertical diameter (Plate LVIII, 7).

(2) *Changes of the Thoracic Viscera.*—The deformed spine usually displaces the rather loosely connected structures, such as the esophagus, or the vena cava. The aorta being closely attached to the spine by means of the intercostal and lumbar arteries becomes deformed only as it follows the tortuous path of the vertebral column. In extreme cases kinks and torsions of the aorta occur which may form serious obstacles to the circulation, and especially so if combined with gross displacement of the heart itself. The apex of the heart has

been found displaced as low as the bifurcation of the aorta in front of the promontory. The level of the diaphragm in severe cases of kyphosis is considerably lowered and with it there is also displacement of the organs of the abdominal cavity.

f. **Abscesses.**—Wherever there is extensive destruction of bone an abscess may be assumed to be present. Wandering abscesses, that is, those that leave their original sites and, wandering within fascial planes, finally reach the surface at remote points, are present in about 30 per cent of the cases, if one excludes the intrapelvic and intrathoracic abscesses. The manner in which these abscesses develop has been the subject of discussion in the Section on Pathology.

We see that the most frequent of these abscesses are the retropharyngeal and the supraclavicular, coming from the cervical spine; the paravertebral and mediastinal abscesses, from the dorsal spine; those appearing in Petit's and Grynfeldt's triangles, and the iliac and iliopsoas abscesses, from the lumbar spine (Plate LIX, 1, 2, 3, 4, 5).

In the writer's series of over 200 cases of spinal tuberculosis, abscess was present in 30 per cent of all cases, and in 45 per cent of all dorsal tuberculosis. Fifteen per cent of all cases of dorsal tuberculosis, or 8 per cent of all cases of tuberculosis of the spine in general, showed retromediastinal abscesses.

Vacchelli[193] found abscesses in different localizations in 26.6 per cent of his cases. According to this observer abscesses found in the 1st decade are prevailingly lumbar and lumbosacral, and rarely dorsal abscesses. In the 2nd decade he finds prevailingly the dorsal and the lumbodorsal abscesses. In the 3rd decade the highest percentage is that of the cervical abscess, and following this, of the sacral, lumbar, and dorsolumbar abscesses. In the 4th decade it is again the cervical abscesses which are most frequently encountered; and in the 5th and 6th decades, likewise, cervical abscesses are frequently found.

Drachmann[59] computes the frequency of abscesses for the whole spine at 13 per cent, and Mohr[129] at 12.5 per cent. These clinical percentages of abscess frequency vary greatly from those arrived at at autopsy where the incidence of abscesses is given as high as 80 per cent. This is, of course, explained by the fact that many of the tuberculous abscesses do not reach the surface or attain sufficient size to become of clinical significance. Abscesses as a clinical complication may be estimated at 30 per cent, since many of these abscesses, for instance, the prevertebral abscesses, so often found at autopsy, do not become manifest.

g. **Compression Paraplegia.**—Compression of the spinal cord is produced either by pressure of the inflammatory products, such as pus or granulations, which, by devious routes, have reached the spinal canal, or by direct pressure of bone protruding against the spinal cord at the point of angulation.

(1) *Early Sensory Signs.*—The first symptom of pressure may be pain of local or lancinating character, due to pull or pressure upon the roots of the

PLATE LIX

Fig. 1.—Paravertebral abscess.

Fig. 2.—Lumbar abscess through Petit's triangle.

Fig. 3.—Combined lumbar and gluteal abscess.

Fig. 4.—Combined perineal and ischiorectal abscess following sacroiliac tuberculosis.

Fig. 5.—Psoas abscess. (After Wullstein.)

Fig. 6.—Case of spondylitis deformans juvenilis. (Note arcuar kyphosis in contrast with angular kyphosis in tuberculosis.)

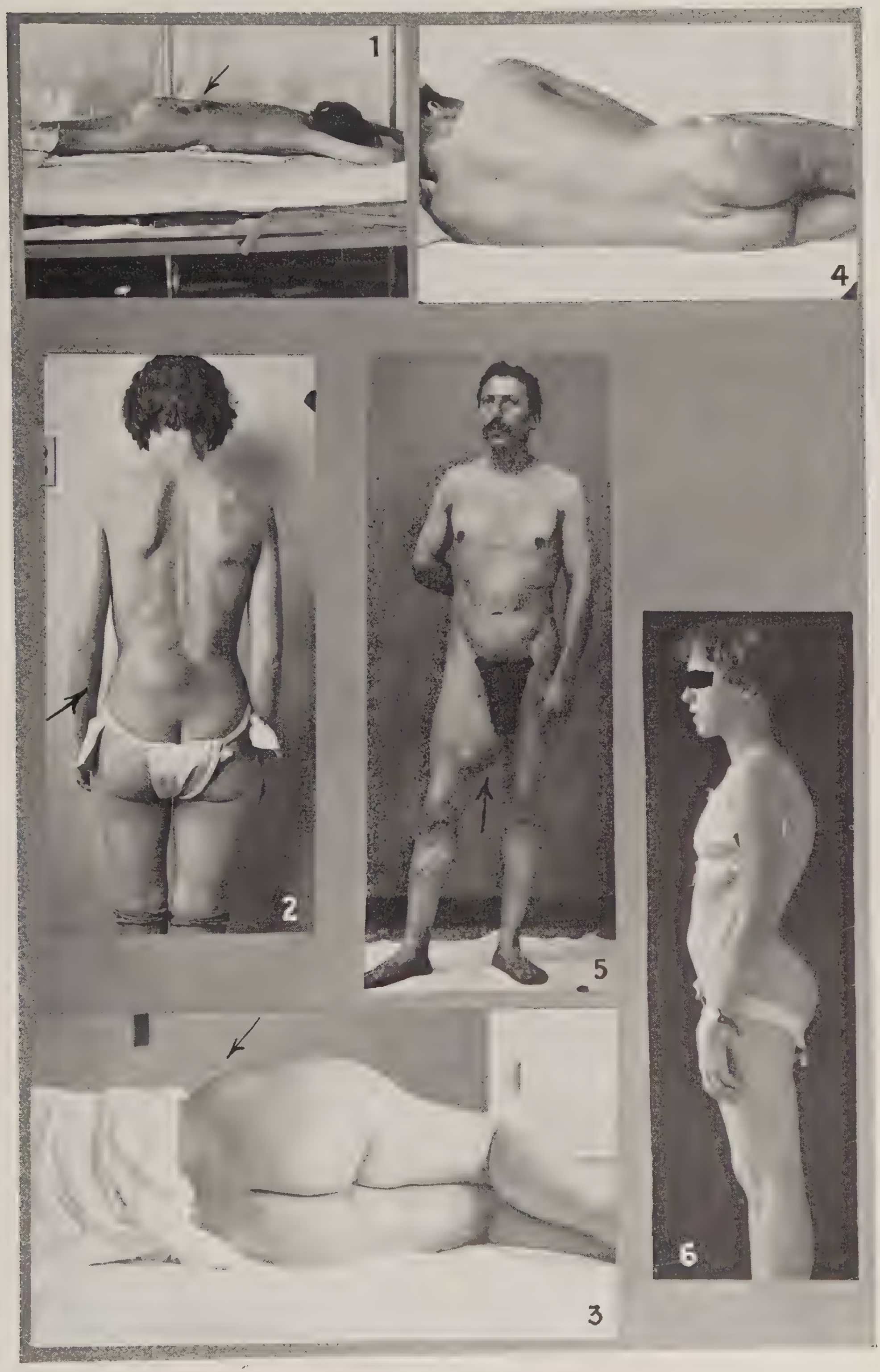


PLATE LIX

spinal nerves. Radiating pains are complained of in the chest, the abdomen, and in the groin and lower limbs.

In cervical spondylitis radicular symptoms appear earlier and with greater frequency as forerunners of compression myelitis. Radiation is distributed along the brachial plexus, sometimes combined with irritative symptoms of the sympathetic system (oculopupillary symptoms).

(2) *Motor Symptoms.*—The typical compression symptoms are of the spastic paralytic type. They consist in muscle rigidity, increased tendon reflexes, and spastic paralysis of the extremities. Disturbances of the functions of the bladder and bowel, as well as trophic disturbances, are often associated with higher degrees of spinal compression. A typical clinical sequence of compression symptoms is as follows: the patients begin to complain of becoming tired, the limbs feel heavy and insecure in walking and develop a certain stiffness and rigidity. The patients avoid forced movements such as running and jumping, they stumble and fall easily, and when they walk briskly they often complain of having difficulty in setting one leg in front of the other. In caries of the lower cervical vertebrae one finds, occasionally, paralysis of the upper extremity as well as of the lower, and of the musculature of the thorax and abdomen. The contractures set in at a much later stage, at a time when the patient is already bedfast. Then appear the flexion, adduction, and inward rotation contractures of the hips, and the flexion contractures of knees and ankles. The flexed knees are pressed tightly against each other, and the limbs are often crossed. In extreme cases of flexion contractures the thighs touch the anterior abdominal wall. Not infrequently contractures are associated with violent lancinating pain in the lower extremities. A tremendous increase of the reflex irritability is often present which causes the limbs to contract spasmodically at the slightest touch or pressure. In later stages, as the degeneration of the spinal cord proceeds, the symptoms change from the spastic to the flaccid type. Occasionally one finds in adult patients that the change from spastic to flaccid paralysis comes on with unusual rapidity, often in the course of one or two days, so that energetic operative procedures, for the relief of pressure, become necessary. One also finds in adults that pressure paraesthesias and compression paralysis precedes deformity and even develops as an early symptom. This is especially true of the epiphyseal forms of tuberculosis of the spine which produce deformities late or not at all. Aside from the motor and sensory symptoms there are also trophic and vasomotor changes, being produced by compression of the spinal cord. Herpes zoster, coldness, perspiration, cyanosis of the limbs, are the most common of the trophic and vasomotor symptoms.

(3) *Determination of Spinal Block.*—In the presence of these undefined symptoms of radiation and nerve root irritation it becomes very important to determine, by examination of the spinal fluid, the existence of spinal compression as well as its level.

The so-called syndrome of Froin consists in massive coagulation of cerebrospinal fluid, hyperalbuminosis with relatively few leucocytes. The syndrome of Sicard and Froix is that of hyperalbuminosis, few leucocytes and slight xanthochromia. According to Roger, Bianchi and Darcourt,[158] these are phenomena of the same nature representing the maximum and minimum manifestations of stasis of cerebrospinal fluid. The upper limit of the compression can be determined by the condition of the sensory innervation, the lower, by the study of the defense reflexes, but it is always difficult to determine with accuracy the upper limit of the sensory paralysis.

(4) *Statistics on Compression Paralysis in Spinal Tuberculosis.*—Pressure symptoms occur most frequently in cervical disease. According to Bouvier,[28] compression signs of any degree are found in 50 per cent in dorsal, and in about the same percentage in cervical disease, making the incidence prorated to the number of vertebrae, twice as high in cervical disease, whereas, only 25 per cent of the cases of lumbar disease show compression symptoms. Wallace[204] finds that paraplegia develops rarely when the disease is below the 10th dorsal. Dollinger,[57, 58] among seven hundred cases, found forty-one paraplegias, or 5.9 per cent, of which thirty-seven were due to dorsal and only four to cervical disease. The statistics of Taylor and Lovett[189] give 13 per cent, and those of Gibney 21 per cent compression paralysis. In the author's series there were, among 220 cases examined, 44 cases, or 20 per cent paralysis, *if* cases showing only exaggerated reflexes were excepted. Of these 44, 13 were complete and 31 partial.

3. Routine Clinical Examination

a. **History.**—In taking the history of the patient the data pertaining to heredity and familial tendencies to tuberculosis, as well as the state of health of the parents and immediate ancestors in general, should be carefully noted. Such familial traits as feebleness of constitution, and general debility of health, flat-chestedness, or susceptibility to colds deserve attention.

Of importance in the early history of the patient are statments regarding nutritional disturbances and feeding difficulties, such as are liable to disturb the progress of development. The rate of increase in height and weight should be noted, the weight curve being of especial importance in judging body development as a whole.

Regarding precurrent diseases much interest should be bestowed upon the contagious group: scarlet fever, whooping cough, and measles. Next the susceptibility to colds, to affections of the upper air passages and of the accessory sinuses, should be ascertained. Then come the data relative to gastric disturbances, constipation, loss of appetite, which indicate early gastrointestinal disorders.

In eliciting the specific trouble one should endeavor to establish the time when, before any definite symptoms appeared, the state of the health has become less satisfactory, and when the loss of appetite, listlessness, disinclination to play, tiredness or an occasional change in disposition were first noticed.

Loss of weight and occasional afternoon temperature are often the first definite signs of general nature. Definite signs of local character for which medical help is solicited appear in the history as abnormal posture, unusual gait, attitudes, rigidity of the body, easy fatigue, an uncertainty in locomotion. They are followed by immediate signs of local or referred pain and by deformity.

b. Physical Examination.—With the complete history established one then proceeds with the physical examination of the patient by having him first fully undress, and then examining him in standing position. One notes the general habitus, anemia, emaciation. Abnormal attitudes of posture, gait and carriage, become apparent. The patient is then told to go through the ordinary motions of walking, running, stooping, squatting, sitting and arising. The patient's manner of turning, of bending, of arising from the floor, of picking up objects, of holding his head, and using his hands in support of his body, etc., may become significant.

The patient is next placed prone upon the table. The rigidity of the spine is first tested by palpation and by carefully lifting feet and legs so as to see whether the lower spine will sway and follow the movement of the hips in a normal manner, or whether it will maintain itself in a state of rigidity. The same test is given to the muscles of the neck. The spine is further examined for local tenderness upon pressure. The cervical and upper dorsal spine is examined as to mobility by moving the head; the lumbar spine, by moving the body, sideways and posteriorly. Abscesses are looked for by palpation and percussion, at both sides of the spine, at the cervical triangle, in the axilla, at the posterior intercostal spaces, in Petit's triangle, as well as in the region of the sacrum and of the gluteal muscles. Next the body is examined for glandular involvement at neck, axilla, groin and elbow. Percussion and auscultation of the lungs in the back, and the testing of the posterior respiratory expansion must not be omitted.

The patient is then turned upon his back and the examination proceeds with establishing the reflexes of the lower extremities: knee reflexes, Achilles reflexes, Babinski. One notes the rigidity of the muscles and the restriction or freedom of motion in ankles, hips, knees. Then follows the testing of the cremaster reflexes, the umbilical reflexes, and the reflexes of the upper extremities as well as the pupillary reflexes.

The mobility of the spine in all its sections and in all directions is again tested. The outlines of the lungs and heart, the position of the diaphragm, and the anterior respiratory excursion are then determined. Abscesses are looked for in the lateral triangles of the neck, the supraclavicular fossa, in the axilla, in the groin, in the iliac fossa, below Poupart's ligament, at both sides of the thigh, in the perineal and ischiorectal regions.

The test for the mobility of the hip is of particular importance as it shows if there is any evidence of a psoas abscess which would interfere with extension movement in this joint. The relaxation or rigidity of the muscles, especially that of the abductors, adductors, hamstrings, and gastrocnemius, is important as showing or excluding beginning paralysis. Examination of the cutaneous and deep sensibility follows.

In examination of the lungs attention should be paid to evidence of old pulmonary involvement. Auscultation and percussion should further determine the presence of abscesses and accumulations of fluids in the retromediastinal space.

It is hardly necessary to say that a general examination which includes that of heart and lungs and of the intestinal tract, of the upper air passages, and a thorough examination of the blood and urine must be given to every patient.

c. The Diagnostic Value of Tuberculin.—The greatest value of the tuberculin reaction, both in cutaneous and subcutaneous tests, lies on the negative side. Owing to the great sensitiveness of the test, tuberculosis may be excluded on the grounds of a negative reaction. In children under five, the positive outcome is also of diagnostic value as it strongly indicates the tuberculous nature of the surgical condition under investigation. But in older children and in adults a positive reaction may refer to any previously acquired and long healed tuberculous focus, and may not have any connection with the lesion examined.

Schultz,[175] studying the value of old tuberculin Koch for the diagnosis of bone and joint tuberculosis at large, and using the cutaneous or Pirquet method, and the intracútaneous as well as the subcutaneous injections, finds that clinically positive cases also show a positive test in 81 per cent of the cutaneous, in 100 per cent of the intracutaneous, and in 87.5 per cent of the subcutaneous tests. Definitely nontuberculous cases showed a positive test in 40 per cent of the cutaneous, in 9 per cent of the intracutaneous, and in 40 per cent of the subcutaneous tests. In doubtful cases it was shown that the local reaction became very indefinite in tests of all kinds.

The general reaction appeared positive in 80 per cent of cases of proved tuberculosis, and in only 2 per cent of nontuberculous, but in 25 per cent of doubtful cases. This shows that in clinically doubtful cases, tuberculin reaction is of value, only, if negative. Subcutaneous injections are also unsatisfactory and in large doses not without danger. The focal reaction is likewise unreliable.

Within the last decade the value of tuberculous complement-fixation test has likewise been investigated. According to Keller and Moravek[101] the complement fixation test is usually negative before the lesion has developed, but it is of great diagnostic value where an undefined lesion is present, but no pathognomonic sign has as yet developed. Among cases with an appreciable lesion but with lack of definite symptoms they found this test to be positive in 76 per cent. Apparently normal individuals, even with healed tuberculous infection, will invariably give a negative complement-fixation test, which therein differs from the tuberculin test. From the reports of Keller and Moravek,[101] it is also possible to determine by complement-fixation test whether a patient is afflicted with tuberculosis of the bovine or the human type.

d. The X-ray in the Diagnosis of Spinal Tuberculosis.—Gross destruction in form of circumscribed defects, erosions, and necrotic areas is easily determined. Lateral views are often necessary to bring out the wedge shape of the vertebra. More difficult is the interpretation of slight changes in contour, of haziness and blurring, especially around the intervertebral articulations. Marked condensation of bone such as seen in later stages of osteochondritis is sometimes noted within the vertebral bodies. It usually signifies telescoping of the body with a molecular necrosis followed by increased calcium deposits. Aubrey and Pitzen[12] found that shadows are most dense in the middle of the focus and decrease toward the edges. But it is the return of sharp contours and of heavier shadows and the signs of trabeculation rather which are significant for progressive repair. Mere apposition of bone does not, necessarily, mean repair; this is evidenced by hypertrophic changes seen occasionally in tuberculosis, sometimes concurrently with destructive changes. These bone bridges between vertebrae firmly ankylosing the bodies by periosteal overgrowth are not infrequent findings (Cofield[46]). They are usually seen in the adult, much less frequently in children and adolescents.

The x-ray picture is also of great value for the recognition of tuberculous abscesses. Above all things one must be able to differentiate the abscesses from other, normal, shadows, or shadows produced by other pathologic conditions.

In the first or second year of life, the thymus shadow overlapping the large vessels may be misleading. The aorta is seen on the left side of the spine commencing at the level of the 4th dorsal vertebra, having a width of 1 to 3 cm. The heart shadow hardly gives rise to error unless it be the shadow of the right ventricle as it overlaps the right border of the spinal column.

The outlines of the psoas muscle, however, often cause mistakes in interpretation. This shadow presents an acute triangle at both sides of the lumbar spine. The lateral sides are sharp and straight. They lead laterally to a point where the shadow of the iliac crest makes a swing horizontally outward. The enlargement of this shadow laterally is suspicious for psoas abscess.

There are a number of pathologic formations of other nature which may simulate tuberculous abscess. Some of these lie in the spine itself, for instance, tumors of the spine, or outside of it, such as tumors of the lung, enlarged hilus glands, etc.

In cases of aortic aneurysm casting a shadow, the fluoroscopic examination becomes necessary to determine the pulsation of the tumor.

Having recognized the shadow as an abscess, one often finds it difficult to decide whether it has any connection with the spine or is a formation of different origin. The shape of the abscess helps in the decision. In the dorsal section one sees spindle shaped abscesses which extend along the whole section of the spine as circular or flat contoured shadows. Pear shaped shadows are seen in affliction of the lower dorsal spine; these abscesses wander downward and are stopped in their descent by the diaphragm upon which they squat with a broad base. In the lumbar spine the form of the psoas shadow has already been mentioned; in intensity and width it differs from the normal outlines of the psoas muscle. Occasionally a gallstone or a kidney stone may be mistaken for incrustated or calcified old tuberculous abscess.

VI. DIFFERENTIAL DIAGNOSIS

Of conditions which require differentiation there are only comparatively few in infancy; there are many more in older children and adults in whom complications of the internal organs, arthritic conditions, tumors, and the various forms of traumatism are added to the problems of differential diagnosis.

1. Juvenile Conditions

a. Rachitic Deformities.—The rachitic kyphosis can be distinguished from Pott's disease principally by the absence of rigidity and muscle spasm, by the greater degree of mobility of the spine, and by the arcuar shape of the gibbus. The x-ray pictures in side view show the characteristic rachitic changes and fail to reveal destructive lesions. Other rachitic stigmata usually present themselves. Difficulties may arise in cases of dorsum rotundum or vertebral epiphysitis (see Chapter II). In favor of the latter condition one notes the insidious development of the deformity, the absence of subjective symptoms, and of disturbance of function. Occasionally, however, one may be misled, even with a careful history and good clinical and x-ray examinations. Salaghi[165] reports a case of a patient nine years of age with cervicodorsal kyphosis. This was considered rachitic until symptoms of urinary incontinence appeared. There was only moderate prominence of two or three spinous processes in middorsal region, but there was spasticity of the lower extremities.

Even in case of abscess formation errors are possible as the abscess may arise from other sources. Another case reported by Salaghi was a girl of seventeen with severe kyphoscoliosis and previous edema. An abscess appeared on the left breast issuing a great quantity of pus, so that the condition was considered to be costal caries. Finally it was found that the abscess arose from dorsal tuberculosis and that it had extended into the posterior mediastinum, disturbing glutition and respiration, and had penetrated into the pleural cavity. From there it extended toward the anterior wall of the thorax to appear in the mammary region, and, after a short interval, perforated into the esophagus.

b. Scoliosis.—Of all types of scoliosis the congenital form is most likely to mislead, because of its occasional sharp angulation. In the x-ray, a wedge formation may be interpreted as tuberculous destruction, as natural fusion, or as product of repair.

The diagnosis rests upon the history, the recognition of vertebral anomalies, their association with other anomalies of the spine and thorax at different levels, as well as upon the absence of subjective symptoms and functional impairment.

c. Tuberculosis of the Hip.—Differentiation between psoas abscess and tuberculosis of the hip is, as a rule, not difficult. The psoas abscess restricts only the extension and somewhat the outward rotation of the hip joint.

d. Regional Abscesses.—Still, abscesses appearing in the groin may often be of other origin, though they appear to be iliac or psoas abscesses. Suppurative myositis of the posterior abdominal wall from metastatic infection or an infected hematoma may find its way into the psoas sheath. Often infections of the kidneys, particularly those having their origin at the lower pole, may gravitate into the psoas sheath. Intraperitoneal infections originating from the hollow viscera, as well as infections of the internal genital organs may take a similar course, and in the end may, under considerable tension, break through the psoas fascia and appear as psoas abscess. Also in suppurative lymphadenitis the lymph nodes lying between the level of the 2nd lumbar and the bifurcation of the aorta may break down into the psoas sheath and appear as psoas abscess (Baer, Bennett, and Nachlass[15]).

e. Spondylitis Deformans Juvenilis (Plate LIX, 6).—Here, the differential feature is a slow and insidious onset and characteristic x-ray findings. Pain, except in early stage, is the exception. The arcuar deformity occurring in young individuals, the characteristic x-ray findings of fragmentation of the epiphyses, and of changes in the epiphyseal line, usually settle the diagnosis.

Here, also, belong the cases of osteochrondritis vertebralis of Calvé. This is a peculiar, hitherto undefined destructive and absorptive process within the vertebral bodies seen at an earlier age (six to eight years) than epiphysitis, and leading to wedge formation of the vertebrae. (See Chapter II.)

2. Differential Diagnosis in Adults

a. Traumatic Conditions, Spinal Crush (Kümmell's Post-Traumatic Kyphosis).—The history of trauma, and especially the free interval following trauma, the late appearance of pain, the gradual development of kyphosis, and, in the x-ray picture, evidence of crush or compression fracture at the site of deformity, are of importance.

Differentiation is by no means easy in Kümmell's disease since post-traumatic tuberculosis is not impossible, that is, a manifestation of a latent tuberculous focus may follow trauma after due interval. One must depend for the diagnosis of traumatic kyphosis upon the absence of general symptoms, and of abscess formation in the x-ray picture. (Chapter IV.)

b. Deforming Spondylitis.—This is not a localized condition but involves larger sections of the spine and other joints as well. The hypertrophic form which is more apt to give rise to error is a disease of middle and advanced age. Ankylosing spondylitis of the Strümpell-Marie type begins with the lower portions of the spine and moves upward. The pain is not localized. The deformity in spondylarthritis is not of the angular but of the arcuar type, and the x-ray picture usually shows the characteristic arthritic changes. In the types of spondylarthritis associated with involvement of other joints the diagnosis is not difficult. (Chapter IX.)

c. Neuralgic and Myositic Conditions of the Spine.—Lumbago, muscular rheumatism, and the so-called myogelosis or induration of the muscles as described by Pitzen must be differentiated from spinal tuberculosis. In myogelosis there are degenerative interstitial changes seen in the muscle tissue associated with rigidity and pain. Progressive myositis ossificans is a more or less suddenly apearing, painful, inflammatory swelling of the muscles of the back, which results in induration and ossification. This induration might, at some time, be taken for local rigidity of Pott's disease. The x-ray picture, however, usually settles the doubt.

The same is to be said of ostitis deformans or Paget's disease for which the x-ray picture is also characteristic; it shows typical features not only in the spine, but also in the long bones and the skull.

d. Diseases of the Central Nervous System.—For the differential diagnosis certain disturbances of the central nervous system which produce sensory disturbances, atrophies, and impairment of the gait, are of importance. To these belong the cerebrospinal lues and tabes. In the absence of more definite specific symptoms, early signs of spinal compression may lead to confusion, for instance, root symptoms. Blood and spinal Wassermann tests usually determine the diagnosis. (Chapter VIII.)

e. Chronic Pyogenic Osteomyelitis (See Chapter VII).—The primary chronic osteomyelitis of the spine is rare. Osteomyelitis of the spine usually starts with an acute stage; also, in pyogenic osteomyelitis the involvement of the posterior portions of the vertebra is more frequent than that of the body, in contrast with tuberculosis of the spine. Actinomycosis of the spine (see Chapter VII) is a very rare disease and extremely hard to differentiate unless the characteristic sulphur granules are recovered.

Typhoid Spine (See Chapter VII). This lesion is generally located in the lumbar section. There is very little tendency to suppuration. It begins in the convalescent stage of typhoid fever with pain in the back and lumbar region. There is always a great deal of muscle rigidity. Occasionally one finds an arcuar kyphosis.

Spinal cord symptoms such as paraesthesias, paresis and disturbance of reflexes are frequent. The Widal test is positive and in the x-ray picture the characteristic ossification of the ligamentous structures is seen. One notes the disappearance of the intervertebral disc, and the fusion of the vertebrae.

f. Luetic Arthropathies (See Chapter VIII) of the Spine. Tabes and Syringomyelia.—These conditions are characterized by osteoporosis of the vertebrae, spontaneous fractures and collapse, and the formation of kyphotic and scoliotic deformities. In arthropathies the hypertrophic changes are very excessive; there are paravertebral ossifications, and ossifications of the long ligaments and of the reinforcing structures of the articulations. All this produces a very unusual and characteristic x-ray picture. There is, in addition, considerable deformity, absence of pain, remarkable preservation of the mobility of the spine and no muscular contracture. Similar conditions are observed in syringomyelia, but here the scoliotic deformity is usually in the cervicodorsal section. Differentiation is, as a rule, not difficult.

g. Spinal Neuralgia and Spinal Irritation.—Spinal neuralgia and irritation must be considered as problems for differential diagnosis. They also lead to muscle fixation of the spine and to functional disturbances. Spinal irritation following trauma is often very difficult to differentiate from organic bone disease, especially so since it may become superimposed upon an original organic, ankylosing type of spondylitis. Cases manifesting hysterical symptoms combined with severe changes of the spine are described.

Intercostal pain often appears in neurotic spines in form of intermitting or constant neuritis, and is also often observed in Pott's disease. The attitude of the patient in general, neurotic or hysterical stigmata of other nature, absence or presence of anatomic corollaries, demonstrable in the x-ray, to his subjective complaint, must be considered to differentiate the functional from the organic element. (Chapter V.)

h. Root symptoms.—Sometimes abscesses coming from the lumbar region following the hypogastric and the inferior gluteal artery, and leaving the pelvis through the greater sciatic notch, to appear finally in the gluteal region, may cause violent pain corresponding to the distribution of the obturator nerve. This is due to compression by the abscess, or granulation tissue, of the roots of the 2nd to 4th lumbar nerves.

Root symptoms are more common in tuberculosis of the spine than is generally supposed. They may simulate ulcers of the stomach or gall bladder disease, renal colic, uterine or ovarian trouble. Cases have been operated upon for appendicitis or gall bladder disease because of pain in these regions, which ultimately proved to be cases of spinal tuberculosis with pressure symptoms from lumbar roots.

i. Tumors of the Spine (See Chapter X).—Of greatest moment is the differentiation between spinal tuberculosis and tumor. Metastatic carcinoma of the spine most frequently follows tumors of the mammary gland or prostate, occasionally, also, carcinoma of the thyroid or of the uterus, or a malignant hypernephroma.

The usual seats of the metastases are the bodies of the dorsal and lumbar spine. Angular gibbus formation, however, is rare; more commonly there is a massive collapse of the spine.

Sarcoma occurs as a primary or secondary tumor and is of greater malignancy than the carcinoma. There is a rapid development of pressure symptoms of the posterior roots with incontrollable neuralgic pain.

Points of differentiation for malignancy are: evidence of a primary tumor, cachexia (not a constant symptom in earlier stages), pain, uncontrollable either by position or immobilization, and the x-ray findings. The diagnosis of tuberculosis rests upon the history, the findings of destructive lesions in the x-ray, the formation of an abscess, and the deformity.

The multiple myeloma causes, in contrast to tuberculosis of the spine, an arcuar kyphosis and is associated with symptoms of compression of the spinal roots. Characteristic for this condition are myelomatous metastases of other bones, the blood picture (myelocytes) and often the presence of Bence-Jones bodies in the urine (proteinuria).

In carcinoma there is also root pain, uncontrollable by either support or position, appearing as an early symptom. Deformity appears late, if at all. The effect upon the general health, rapid loss of weight, severe secondary anemia, emanciation and cachexia distinguish malignancy from a moderately advanced tuberculosis.

In the x-ray picture myelomatous or carcinomatous metastases of the spine present themselves as characteristic defects with very little reactive bone formation around them, except in the so-called osteoplastic carcinoma of the spine, which shows reactive bone formation around the tumor. Sarcoma occurs in younger individuals and is more rapid in its destruction than tuberculosis. The lumbar and lumbosacral regions are most frequently involved in carcinoma and sarcoma.

Osteoporotic conditions of the spine may give rise to erroneous diagnoses. Arteriosclerosis causes general osteoporosis and atrophy, but it differs from atrophy in tuberculosis in that it is diffuse and often associated with arthritic lipping. The same applies to osteomalacia and ostitis fibrosa, although a localized spinal collapse is occasionally seen in these conditions. In the x-ray picture it is, as a rule, easy to recognize the general systemic nature of the condition by the distribution of the lesion over large sections of the spine.

In general, spinal tuberculosis offers no great difficulty for diagnosis. The percentage of diagnostic errors is low on the average, though considerably higher in early stages. One may divide the points of distinction in those pertaining to early diagnosis and those applying to the fully developed clinical syndrome. Practically in all conditions the history carries the greatest weight, especially as it reveals general factors of importance such as heredity, environment, familial tendency, predisposing diseases and tuberculous taints. In early stages the diagnosis depends upon probability signs which must be assessed according to their relative significance and to the manner in which they fit into the whole frame of symptoms.

The absolute diagnosis is made in the presence of a kyphosis, of compression symptoms, of paralysis, of abscess formation, and of positive x-ray evidence, but all these appear comparatively late in the course of tuberculosis of the spine.

VII. PROGNOSIS AND COURSE

1. Mortality Statistics

One of the most important factors in tuberculosis is age. The outlook changes rapidly for the worse as adult or middle life is reached. Many observers think that after the fortieth year complete cure does not occur. The value of general statistics on the mortality in Pott's disease differs according to the individual manner of arriving at the statistical data, and also according to the individual types of treatment favored by the several observers.

Some of the more authentic mortality statistics give the following figures: Vulpius,[201] for the cervical region 16 per cent, for the dorsal 28 per cent, and for the lumbar spine 7 per cent mortality, Vacchelli,[193] 16.5 per cent in all cases; the highest mortality is shown in the cases complicated by paraplegia, namely, 43.5 per cent, then follow the types of hereditary tuberculosis with 18 per cent, then the cases complicated with abscess formation with 17.10 per cent mortality.

The highest mortality percentage is seen in middle age and in cases of longer duration. This is not strange since pathologic examination shows that the repair of the diseased focus in adults never reaches the point of thoroughness seen in children.

2. Immediate Causes of Death

Most frequent among these is recrudescent phthisis of the lungs and tuberculous meningitis. The former is more often seen in adolescents and adults, the latter in children.

Next in importance is paralysis. According to the author's observation, paralysis, not remediable, sooner or later leads to death by development of the decubitus, pyelitis, and general sepsis. In general, the "closed" tuberculosis, i.e., without establishment of communicating abscesses or sinuses, offers a much better outlook for life than cases in which these complications exist. With all precautions it seems impossible to ward off the fate of severe septic complications and it is maintained by Calot,[37] not without grounds, that spontaneous perforation of large abscesses in adults almost always leads to death.

3. Prognosis as to Cure

Cures are given at various percentages ranging from 85 per cent (Rollier) to 30 per cent.

One obstacle in arriving at accurate percentages of cure lies in the difficulty of differentiating between recrudescences of existing conditions and true recurrences. If a period of two or three years of complete quiescence of symptoms can be considered sufficient to call the disease arrested, the writer's statistics show a recurrency rate of 15 per cent.

The highest percentage of cures, under conservative treatment, is obtained in uncomplicated cases of cervical spondylitis. This percentage falls considerably when complications, abscess or paralysis, are present. The unfavorable effect of sinuses and mixed infection upon the percentage of cures has been discussed. In general, the outlook for cure in tuberculous spondylitis is not unfavorable. Simple cases with a limited original focus have an average duration in the cervical region of two years, in the dorsal of three to four, and in the lumbar of four to five years. In cases complicated with abscess the determining factors are: the region of the spine involved, the age of the patients, and whether the abscess remains closed or perforates through the skin (Ridlon[153, 155]).

Cases complicated with abscesses, not perforating, usually have a good prognosis in children, especially in the higher regions of the spine where the size of the abscess is less extensive than in the lower sections. On the whole, the lower the seat of the disease, the greater is the tendency to abscess formation and the greater the amount of abscess material produced. The favorable prognosis for the closed abscess has the following exceptions: first, in the cervical spine the retropharyngeal abscess renders the prognosis unfavorable; second, in the dorsal spine the retromediastinal abscess is a serious complication because of its effect upon the mediastinal structures, and upon the spinal cord; and third, in the lumbosacral tuberculosis the retroperitoneal abscess gravely compromises the outlook because of its effect upon the structures of the peritoneal cavity.

The prognosis of perforating abscesses is much graver and more so in adults than in children. The mixed infection increases the danger principally in those abscesses which, by their localization, become difficult to control, especially the retroperitoneal abscess which gains the lesser pelvis and then wanders downward in the gluteal region and surrounds the hip joint. These complications belong to the most severe and fatal ones in spinal tuberculosis.

4. Prognosis as to Deformity

A minority of cases heal without deformity. To these belong the epiphyseal forms seen mostly in adults. This does not mean that deformity is absent always or even in a majority of cases, but the telescoping frequently occurs without angulation and results merely in a shortening of the spine. In a majority of cases, however, a deformity develops in the form of a gibbus, more rounded if a greater number of vertebrae are involved and more angular if the disease is more localized.

Ridlon[153, 155] believes that cases treated with sufficiently prolonged recumbency can be cured without increase in the kyphosis, and that cervical disease, unless kyphosis is of long standing, can be cured without deformity, and, that, as a rule, a very considerable degree of normal mobility can be obtained. In dorsolumbar disease considerable reduction of the deformity can be obtained by prolonged recumbency. In upper dorsal disease the curvature is likely to increase under any form of treatment, and, in these cases, prolonged recumbency is especially essential (Ridlon[153, 155]).

The factors upon which the prognosis as to deformity depends particularly are: location of the disease and thoroughness of treatment. A deformity which is not yet consolidated can be fully corrected in the cervical spine and can be reduced in the dorsolumbar region, but in the upper dorsal spine, as a rule, some deformity results. If the diagnosis is made before deformity has occurred and if proper treatment is consistently carried out, deformity may be prevented in most cases and the duration of the disease, thereby, greatly shortened. Ridlon believes that no case should be under treatment and observation for less than three years and in many cases five years or longer.

The contrast between cases properly treated and cases abandoned to medical treatment alone, or to no treatment at all, can be seen in some statistical reports, in which the death rate mounts to over 25 per cent, and the cures fall below 50 per cent (Rozoy); in contrast with this are the statistics on conservative treatment, particularly recumbency and heliotherapy. (Rollier[159] 85 per cent—see later.)

5. Prognosis of Paraplegia

Because compression paraplegia is mostly moderate in degree and because it readily responds, as a rule, to recumbency, the prognosis in the great majority of spastic cases is favorable. This applies particularly to children in whom adequate and prolonged recumbent treatment is nearly always successful. In adults, however, the prognosis of paraplegia becomes much severer, since it does not yield so readily to treatment.

Some of the cases not relieved by recumbency improve after decompression operation; even with inclusion of operative procedures, there remains, in adults, still a considerable percentage of cases with unfavorable outcome of the paralysis.

The combined statistics of Taylor, Lovett,[189] Mohr,[129] Reiner, Dollinger,[58] and Vulpius,[201] embracing one hundred and ten cases of paralysis, show fifty-eight, or 52.7 per cent, cured, including the severest form of paralysis in children as well as in adults. Of seventy-four cases reported by Gibney,[74] 77 per cent were cured or improved. While the severest form of unrelieved paralysis almost invariably leads to death, many of the milder cases may persist indefinitely, the patient showing exaggerated reflexes, a certain weakness of locomotion, ataxic gait and easy fatigue.

VIII. THE TREATMENT

1. General Treatment

At all times the treatment for tuberculosis of the spine must be both general and local. In certain stages of the disease the general treatment may require the principal attention because of the delicate condition of the patient, while in others, where the general condition approaches the normal, the local treatment comes more into the forground. In no event, however, must the systemic state of health be lost sight of.

The general treatment includes the following elements: (a) the dietetic treatment; (b) hygienic management; (c) outdoor life, sunshine.

a. The Diet.—It would seem obvious that a diet must be adopted which fits the need of the particular type of treatment. What the patient afflicted with tuberculosis of the spine should eat during recumbency or during the ambulatory stage is too important to be left entirely to lay judgment. Food should be both regular and plentiful. If the patient is in recumbency, starchy food should be restricted, but eggs and milk given in abundance. Meat is usually not very well borne and should be given in moderate quantities only. Above all, the food should consist in milk, cereals, cream, and fruit. The main meal should offer some meat, at least two vegetables, possibly three, rich in cellulose, some fruit, and cereal. For the evening meal, milk, also cereals and fruit can be recommended. As a rule, tuberculous children should be kept on a higher protein allowance than normal children but there is no reason to increase the carbohydrates beyond what would be appropriate for a bedfast patient. The general nutrition may be further improved by olive or cod liver oil, or by some of the malt extracts. As a tonic to stimulate the appetite, syrup of ferric iodide or iron, quinine and strychnine are useful.

For elimination mineral oil given at bedtime and ample fluids, fruit juices, fig serum are usually sufficient, only occasionally a stronger laxative will be required.

b. Hygienic Treatment.—Exposure to air and outdoor life is such an obvious advantage to the general state of health that it hardly needs emphasis. The systematic exposure of tuberculous patients to the sun, however, based upon modern and scientific principles has only recently developed into a powerful factor in the plan of treatment.

c. Heliotherapy.—(a) Historical.—In his treatise on "Air, Water, and Sun," Hippocrates emphasized the favorable influence of the latter. In fact, since time immemorial, exposure to the sun has been recognized as a factor in general health. Heliotherapy, however, did not rise to a regular, standardized method of treatment until so developed by Rollier[160] and Bernhard,[23] in more recent years. The first studies on the physiologic and chemical effect of sun baths date back to 1816 when Döbereiner, a chemist, studied and described the effect of sunlight upon the skin, the influence of light clothes, the wearing of light colors, etc., upon the general health. Rollier's effort to develop sun treatment as a standardized method dates back to 1902. He and Bernhard, stimulated by the work of Finsen[63] (1899), and favored by the unexcelled climatic advantages of Switzerland, introduced in that country heliotherapy on a larger scale. The effect of dry sunlight at high altitudes was recognized as the result of the direct bactericidal and stimulating action vested in the violet rays of the sun, which are especially plentiful at high altitudes. To-day, heliotherapy has conquered for itself a definite place in the treatment of surgical tuberculosis and has come into general recognition.

(b) Physiologic Action of Sunlight.—The best known action of the sun is that upon the skin where it produces pigmentation or reactive inflammation known as erythema solare. The latter is merely a pathologic degree of the normal reaction to sunlight, and it is principally produced by the ultraviolet rays. The pigmentation produced by sunlight is a protective measure against the light and it disappears as the light irritation ceases. Patients who acquire pigmentation easily respond more favorably to insolation, and we find that in brunettes insolation usually produces better results than in blondes. In the pigmented area of the skin there is noted an increase of hair growth and increase of growth of the nails. Pigmentation takes place most intensively between the months of March and May. It seems that for the therapeutic effect the difference between the temperatures in shade and sun is of especial value. The difference amounts to only 5.6 degrees at 20 m. above sea level, but rises as high as 53 degrees (C.) at altitudes of 3,000 m. (Harms[82] quoted by Bernhard). This explains the applicability of sun treatment throughout the whole year in such favored places of high altitude as Leysin, Davos, St. Moritz, etc.

(c) Pathologic Changes.—Pathologic changes and disturbances can be produced by sunlight and if insolation is to be carried out with any degree of safety, one must watch for the irritative effect and arrange the dosage of insolation in proportion to the tolerance of the patient. Careless insolation may lead to real disturbances of the temperature centers of the brain and produce sunstroke, especially under exertion. The symptoms of overinsolation are dry and burning skin, strongly overheated face, fatigue and headache. Proper precaution must be taken to prevent such complications (see Technic of Heliotherapy).

(d) Heliotherapy Institutes.—Attracted by the splendid results obtained by Rollier, Bernhard and others, not only have a great many orthopedic surgeons included heliotherapy in their routine treatment of surgical tuberculosis, but institutional heliotherapy has come much into the foreground. Aside from the establishments in Leysin, Davos, and St. Moritz, one, more recently established, is that of Cortina D'Ampezzo in the Dolomites connected with the Institute Rizzoli, and under the direction of Dr. Putti. This place has an altitude of 1300 m. Unfortunately in low lands and in changing and unstable climates a great deal of the advantage of heliotherapy is lost because of the shortness of the sun days and comparative scarcity of the actinic rays in the unclear atmosphere of lower altitudes. Though not favored with the climatic advantages of the great institutions in Switzerland and Italy, heliotherapy in this country is also being used on an increasingly larger scale. The best known institutions are the Adams Memorial at Harrisburg and the Peabody Home at Boston. Besides these, there are in all of the larger and most of the smaller orthopedic centers ample provisions made for the sun treatment of surgical tuberculosis (Plate LX, 1).

(e) The Technic of Application.—According to Rollier, who elaborated a detailed insolation technic, the patient is started at five minute periods of exposure as follows: on the first day the legs are exposed five minutes, on the following day ten minutes exposure is given to the legs and five minutes to the thigh, on the third five minutes to abdomen, ten minutes to the thigh and fifteen to the leg, etc., on successive days, until the patient becomes entirely tolerant to the insolation of the whole body. After he has been insolated for an hour or an hour and a half a general insolation throughout all the hours of sunlight can be carried out (Plate LX, 2).

The precautions necessary to avoid untoward complications during insolation are proper control of pulse and temperature, protection of the head, the application of cold bandages, and the administration of ample fluids. Patients complaining of dizziness or headache must be taken inside.

The patient is held recumbent either in dorsal or ventral position. In the dorsal position he is placed flat upon a hard mattress; only when the patient is in an emaciated condition is it necessary to place a cushion between gibbus and mattress. A ring cushion is used for the support of the pelvis and for the sacrococcygeal region, and a second cushion to support the lumbar lordosis. A small cushion is also placed under the patient's head. In children or restless adults an additional strap of canvas or a canvas waist is attached to the mattress to prevent the sliding of the body. When the gibbus has been reduced or flattened out and the skin over it has become less tender, the cushion under the gibbus can then be replaced by a wooden plank 2 to 3 cm. in thickness with slight convex upper surface. The ventral position in recumbency is adopted after a few weeks of sun treatment, when the pain has disappeared (Plate LX, 3). This position assumed during the day gives sufficient repose for the spine and removes completely the pressure of body weight; it favors also the formation of compensatory lordosis, and permits radiation of the whole back. In this prone or ventral position a cushion is inserted under the chest and gradually increased in width, thereby increasing also the lordosis above and below the deformity. A prominent gibbus in the lumbar or dorsal spine may be corrected by this procedure, and in early stages of spondylitis, deformity may thereby be prevented.

For the cervical spine the Glisson swing is used, or, in order to avoid its constricting effect upon the lower jaw, a celluloid cup molded from a plaster cast of the neck and occiput may be used, the head resting therein by its own weight and the horizontal pull being exerted upon the occipital prominence.

Under this treatment one gradually sees an erythema of the skin appear as the first sign of reaction. It is rapidly followed by tanning of the skin. The general condition visibly improves; pain disappears, swelling and abscess formation frequently subside. In the x-ray one sees the contours of the vertebrae becoming sharp and distinct, bone production increases as a sign of healthy repair, and the healing process is greatly aided by the functional use of the muscles.

(f) Statistics.—Allison[8] points out that the great disaster in surgical tuberculosis is the indiscriminate operative interference both in adults and chil-

PLATE LX

Fig. 1.—Institutional heliotherapy at Children's Hospital, Iowa City.

Fig. 2.—Treatment table according to Rollier.

Fig. 3.—The ventral position of insulation.

Fig. 4.—Alpine light.

Fig. 5.—Reclination treatment on the curved frame. Lumbar disease.

Fig. 6.—(A) Reclination and traction. (Head and pelvis.) Dorsal disease.
(B) Reclination and traction (head and pelvis). Lumbar disease.

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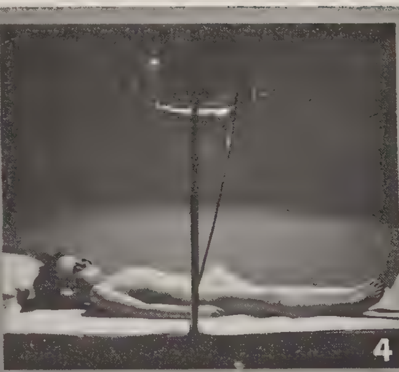

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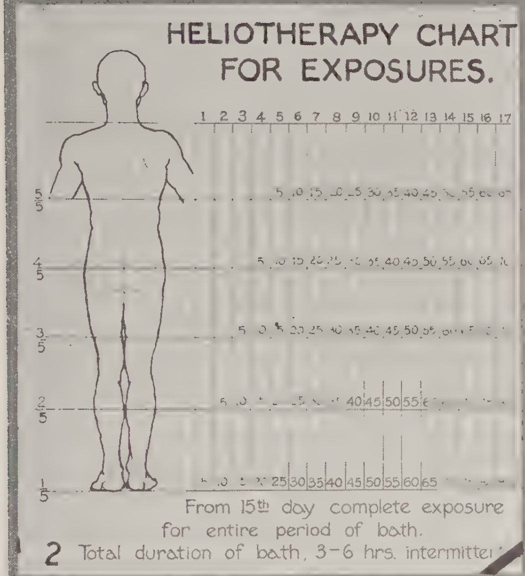

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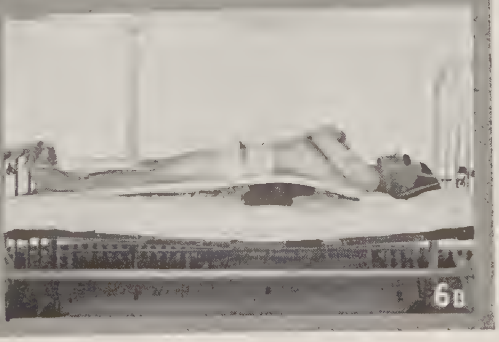


6B

PLATE LX

dren, and that nothing is so apt to restrain promiscuous operating as the remarkable results obtained by heliotherapy and recumbency. In its combination with recumbent treatment, heliotherapy stands out not only for its own specific effect but for conservatism in the treatment of surgical tuberculosis in general. The time element should not be stressed too much as an argument in favor of operative treatment, since it is becoming more evident that all operative procedures, to be safe, require also a long period of conservative after-treatment. Two, three and even more years are spent by patients in Rollier's clinic. Intermissions of the treatment are dangerous. The decision of completed cure rests upon the x-ray evidence. In tuberculosis of the spine the vertebrae must show clearness of outlines and details of texture as well as complete bony blocking of the affected vertebral bodies before repair may be considered complete (Campbell[42]).

Heliotherapy has brought the high mortality figures of earlier statistics (Vulpius, 34 per cent, Mohr, 40 per cent) down to a remarkably low level, especially in combination with recumbency (Putti). Rollier's statistics show the remarkable record of 85 per cent cured. Comparing the results of Rollier's clinic with those obtained elsewhere in less favorable climates, one is struck by the fact that open air treatment and heliotherapy are thoroughly feasible even at lower altitudes or at sea level. Wittek[209] of Graz, for instance, reports excellent results obtained at a level of 400 m. In this country the efficacy of heliotherapy has been amply demonstrated in the various institutions mentioned above. At the Peabody Home for Crippled Children near Boston, situated at sea level with a yearly average of 50 per cent sunshine it has been shown by Ghormley[23] that the weight of the patients increases most in the months with highest percentage of sunshine. In cases of spinal tuberculosis in particular an improvement of the deformity could be obtained to a degree depending upon localization and duration of the disease. Gibbus deformity appeared favorably influenced in the upper dorsal in 30 per cent, in middorsal 50 per cent, in the lower dorsal 66 per cent, and in the lumbar in 90 per cent of the cases (Ghormley). From the Adams Memorial Hospital at Harrisburg, New York, with an elevation of 1660 ft. and a mean temperature of 37° F., equally good results are reported from the combination of heliotherapy and recumbency (Hyde[94] and Lograsso). So we see, that, though the statistical figures of Rollier have not yet been equalled (85 per cent cures of tuberculosis of the spine in children, and 78 per cent in adults), reports from all sources testify to the efficacy of this form of treatment. The definite judgment on the end-results of heliotherapy is obscured only by the fact that it is usually combined with recumbency or other form of immobilization. As an adjunct to conservative treatment, it is of inestimable value; yet, however great its effect may be upon the general condition, the disappearance of abscesses, and the promotion of processes of repair, it must never be allowed to supplant other orthopedic measures, especially recumbency and immobilization (Roederer[157]).

(2) *Alpine Light—Quartz Light (Plate LX, 4).*—A type of light used as a substitute for sunlight is the ultraviolet rays produced in a mercury vapor lamp. It is also known as artificial Alpine light, and consists of a quartz burner contained in an aluminum case in which by a current of 100 to 150 volts light is produced in a quartz tube of 65 cm. length filled with mercury. It is claimed that the ultraviolet ray has a specific beneficial effect upon rickets and other systemic conditions of the skeleton. It is also being made use of as a substitute for sunlight in surgical tuberculosis in local, as well as in general form of application. The local application begins with insolation of three minutes' duration at 50 cm. distance and is extended from day to day until 30 minutes of insolation at the same distance is reached. In the general insolation one begins with three minutes' and a distance of 1 m.; the time is gradually extended until, again, a maximum of thirty minutes is reached, but with each insolation the lamp is also lowered until the minimum distance of 50 cm. is obtained.

In therapeutic effect artificial sunlight is doubtless inferior to the chemical rays of the sun, but during the winter months and in unsuitable climates it is an acceptable substitute. In surgical tuberculosis a certain local effect is noticeable: swellings subside, sinuses after becoming more profuse in drainage, often clear up and close. There is also a decided influence upon local pain. The general effect of this type of treatment is less noticeable.

(3) *Maritime Treatment.*—The beneficial effect of sea air and sea bathing has been known for years. Great institutions are in operation which apply this factor of health to surgical tuberculosis. In France the famous maritime hospitals at Berck sur mer and Berck Plague are devoted to this purpose. Whether or not there is a chemical action upon the body from the inorganic salts contained in sea water and air, its beneficial effect, especially if combined with heliotherapy, seems to be without doubt (Gaibissi[68]). Similar institutes in this country confirm the claims of the wholesome effect of sea air in general and of its value as an adjunct to conservative orthopedic treatment of surgical tuberculosis. The one at Sea Breeze, New York, is the best known. Founded in 1904, it is the first American Institution for the Treatment of Surgical Tuberculosis at the seashore. Whitbeck[206] reporting on advanced and serious cases treated at this institution states that 50 per cent of these were arrested by combination of maritime and sun treatment with orthopedic measures; a high percentage, if considered that many of these cases were in stages of foul, infected sinuses and of amyloid degeneration of the parenchymatous organs.

(4) *X-ray Treatment.*—The treatment of surgical tuberculosis by x-ray is not generally recognized; only sporadic reports on it are at hand and its value is still problematic. Hass,[83, 84] one of the first to apply it to large articulations and to the spine, on the strength of the fundamental work of Freund and others, is a firm believer in its merits. Ventral radiation is more suitable than dorsal, except in the cervical spine where anterior exposure must be avoided

because of the thyroid gland. Lumbar spondylitis and tuberculosis of the sacroiliac articulation are also best exposed from the back.

(5) *Tuberculin Treatment.*—Under various forms and with numerous preparations, the treatment of surgical tuberculosis with tuberculin has been tried and retried periodically. It was first undertaken with the old Tuberculin Koch (O. T.), later with Tuberculin residue (T. R.), also with Tuberculin Rosenbach, representing a synthesis of tubercle bacilli with fungi of other types. The technic of application varies from the simple original Old Tuberculin technic to the insidious and most carefully graduated dosage method of Bonime.[26]

In general, the therapeutic use of tuberculin for spinal tuberculosis has been abandoned, because of the discrepancy of reports and because it is, in efficient dosage, not without risk to the patient. Feldhuhn[62] summarizing his experience with Rosenbach's tuberculin found it very effective in the treatment of surgical tuberculosis when applied insidiously, starting with 1/500 c.c. Similarly, Waterhouse,[205] using Koch's new tuberculin (T. R.) with initial doses of 1/20,000 of a mg. subcutaneously, expresses himself favorably on the effect of tuberculin in surgical tuberculosis. Another advocate of tuberculin, especially if used with Bonime's[26] technic, is Twinch.[191] The reaction of tuberculin lies in its power of producing opsonins by stimulating leucocytosis. Many believe that it rests merely upon the technic of application to render tuberculin valuable, and that the discreditable experiences are due to antiquated methods (Twinch[191]). The initial dose in Bonime's technic is 1/40,000 mg. which is gradually and carefully raised. Under such precautions good clinical results are variously reported (Mayer,[125] Landmann[113]). Ogilvy,[139] by using small doses and controlling the opsonin index, also comes to the conclusion that in mild dosage and proper intervals tuberculin has undoubted value in the treatment of suspected cases of surgical tuberculosis.

The list of opponents to tuberculin treatment is headed by Kleinberg[104] after a number of systematic investigations and considerable clinical experience. This observer concluded that in the majority of cases tuberculin had no beneficial effect upon the lesion. There was improvement in a small percentage of cases, but others again had become aggravated. Ridlon[156] similarly found that tuberculin had no effect in most cases and that in some it proved distinctly harmful.

So it seems that the value of tuberculin treatment has remained doubtful for surgical tuberculosis, whatever its merits may be in pulmonary disease. However, this does not mean that the last word on the efficiency of this method has been said. It is more likely that with improvement of the technic of administration and with more efficient control the beneficial effect of tuberculin in surgical tuberculosis may yet become established.

c. **Educational and Occupational.**—Modern educational methods adapt themselves very happily to bedside teaching; the time spent in recumbency no longer entails the formidable break in the progress of schooling that it did before systematic bedside teaching was introduced in most institutions. The same is true of occupational therapy; for the recumbent as much as for the ambulatory patient it has a great deal to give. Occupational treatment and recreational work should be still stronger emphasized in hospital work and in the home. It develops inclinations, it often discloses natural gifts and talents.

2. Local Treatment

a. **Rest and Recumbency.**—Rest and recumbency have a greater share in the treatment of tuberculosis of the spine than in any other form of surgical tuberculosis; they also constitute the most important phase in the treatment of spinal tuberculosis itself.

Recumbent treatment is indicated:

In all cases with pain or distress, night cries, marked impairment of general health, elevation of temperature and loss of appetite.

In cases with increasing deformity, or rigidity and spasm of the back muscles.

In all cases with developing and increasing superficial abscesses.

In all cases showing signs of spinal irritation or compression.

It is the opinion of many that no case of paraplegia secondary to Pott's disease would develop under adequate recumbency on a Bradford frame. Recumbency is also the safest method of carrying the patient through the acute and subacute stages to the period of repair. The tendency to extend the period of recumbency more and more, at the expense of the ambulatory treatment is, consequently, gaining ground.

(1) Recumbency is, as a rule, combined with *reclination* or traction, or both. Reclination is a position of hyperextension of the back which produces compensatory lordotic curves above and below the seat of disease. This is accomplished by suitable frames, for instance, the gas pipe frame of Bradford. The body, placed in hyperextension by the proper curving of the frame, is fastened to it by straps or belts (Plate LX, 5).

(2) In order to make the immobilization secured in recumbency still more effective, it is combined with *traction.* Traction to the head is applied, by means of the so-called Glisson sling, to the legs and pelvis by adhesive straps or a pelvic belt. Ropes with weights attached to them are run over pulleys fastened to the ends of the bed. The traction applied to limbs and pelvis may serve as countertraction to that applied to the head and vice versa; or, countertraction to the head may be furnished by the weight of the body, if the head end of the bed is raised on blocks, or, the upper part of the body serves as countertraction to pelvic and leg extension, if the foot end of the bed is raised. In high dorsal or cervical disease, the upper end of the frame is sharply curved, so that the overhanging head, by its own weight, furnishes the countertraction (Plate LX, 6a and b). The degree of traction necessary varies with the age and the tolerance of the patient: from 2-3 lbs. at head and 5-6 lbs. at extremities in children, to 10-15 lbs. at head and 15-20 lbs. at extremities in adults.

(3) *Advantages of Recumbency Treatment.*—The virtues of this treatment are complete elimination of weight-bearing and a satisfactory, though not com-

plete, degree of elimination of spinal motion. The advantage of reclination is, in addition, that it produces a mechanical countereffect to the deforming tendency of the disease by forcing the spine into hyperextension. The advantage of traction is that it relieves muscle spasms and contractures and contributes to the immobilization of the spine. It further relieves, indirectly, pressure upon the spinal cord. All have the advantage that they can be carried out in the open as well as indoors, so that the patient can enjoy the benefit of fresh air, sunshine and hygienic measures.

(4) There are certain *disadvantages* to recumbent treatment. Small children adapt themselves very readily to positions of reclination, older ones often have some difficulty; adults frequently respond to it with impairment of the general health, loss of appetite, constipation and feebleness of digestion. This can be met by appropriate modifications of the reclination arrangements, and by a proper recumbency diet (see above) as indicated in the general regime.

(5) *Recumbency, Nursing and Supervision.*—Traction and reclination are simple mechanical devices, but in order to be efficient they must be kept under constant supervision. The duties of the nurse consist particularly in the care and supervision of this mechanical arrangement applied to insure immobilization and to relieve weight-bearing.

In the line of general care it is essential that the skin be given constant attention, that cleanliness may be assured by bathing and sponging so that chafing and pressure sores be avoided. Warm flannel should be worn which can be easily removed when the patient is to be exposed to the sun. Whenever feasible a bed should be arranged on wheels so that the removal into the open air is made easy and convenient. It is important that the bed should be arranged firmly and should not be allowed to sag. Air and water pillows are used to protect prominent places, especially in emaciated patients. The advantage of the frame treatment is that the patient can be turned from the supine to the prone position.

(6) *Details in Technic.*—Some authors (Roederer,[157] Rollier[159, 160]) strongly advocate the prone position in treatment of dorsal tuberculosis as the most suitable one. It is especially apt to counteract developing deformities. The problem of securing the patient to the frame can be solved in different ways. Most convenient is a spinal pillow, or a spinal corset fitted to the frame and fastened over the body of the patient. The frame can be easily carried outdoors and placed on chairs or saw-horses if a suitable cart is not available. An ingenious addition to Bradford's gas pipe frame is that recommended by Gerard and Carrell[44] (Plate LXI, 1). It has a fixation device attached to the head bands of the frame by means of a swivel arrangement. This frame is made of bent quarter inch rod of iron so arranged that it fits accurately over the shoulders and thighs and it is protected by rubber tubing. In order to enable the patient to maintain a sufficient lordosis, Rollier fixes the shoulders with straps to cross in the back, and fasten to the foot of the bed. These straps can

be suitably tightened as the patient lies in prone position, thereby causing the shoulders to be pulled back and facilitating the better development of the thorax.

For cervical spondylitis a Glisson sling is used; it may be substituted by a cup modeled to fit the occiput, so as to avoid the constricting effect of the sling upon the lower jaw. Some use bands around the forehead as anchorage for horizontal traction upon the head. In young children, who are hard to immobilize upon a frame, the hyperextension is best taken care of by the so-called reclination plaster bed, first introduced by Lorenz[120] (Plate LXI, 2). It is a shallow plaster shell molded to the posterior half of the body, applied in prone position with the head and trunk hyperextended. The shell is padded with felt, smoothed, and trimmed at the edges; the child is strapped to it and can be carried around in it. Dollinger[58] uses as a reclination apparatus a combination of a plaster bed and mattress.

Along the same principles of complete elimination of weight-bearing and simultaneous hyperextension is constructed the plaster bed of Schwartz[176] (Plate LXI, 3a, b). It is a posterior plaster shell, modified and made adjustable by cutting it transversely at the level of the apex of the kyphos and joining the two parts by hinges on each side, while a long turn buckle connecting the head part of the shell with a heavy plaster pedestal beneath the buttocks, is used to increase the convexity of the shell and to secure hyperextension.

In order to get the best corrective effect of hyperextension, the frame is so applied that the hinges maintain a definite optimum relation to the boss of the gibbus. This relation Schwartz determined by careful x-ray studies as follows: for the 3rd dorsal vertebra the hinges should be 1½ inches below the apex of the gibbus; for the 4th, 1 inch below; for the 6th, ½ inch below; for the 7th dorsal, opposite the defect; for the 8th dorsal it should be ½ inch above; for the 9th ¾ inches above; for the 10th, 1 inch above; and for the 11th and 12th, 1¼ inches above the gibbus.

In this way the mechanical arrangement of the bivalved posterior shell is calculated to give the best possible purchase for the formation of compensatory curves. The frame is comfortable and easy to handle and may be put to good use both in the home and in the hospital.

(7) *Is recumbency indispensable for elimination of weight-bearing stresses?*—Since the most valuable therapeutic factor of recumbency lies in the elimination of weight-bearing, one may be justified in asking whether this advantage could not be secured by reclining the body in upright position sufficiently to relieve the vertebral bodies at the site of disease from superincumbent weight.

If so, the principle could be introduced into the ambulatory treatment and combined with the use of an apparatus or corset or brace. The general opinion, however, is that corsets or plaster jackets are insufficient as weight-relieving measures, and they are, therefore, not regarded as substitutes for the recumbent treatment. In addition, there is experimental evidence to show that retentive

PLATE LXI

Fig. 1.—Carrell frame. (Courtesy of Dr. Carrell.) (Explanation in text.)

Fig. 2.—Lorenz reclination plaster bed (anterior and posterior shell).

Fig. 3.—(A-B) The Schwartz frame (explanation in text).

Fig. 4.—Plaster jacket for high dorsal disease (front and back).

Fig. 5.—Goldthwaite frame (after Goldthwaite) for application of cast in supine position.

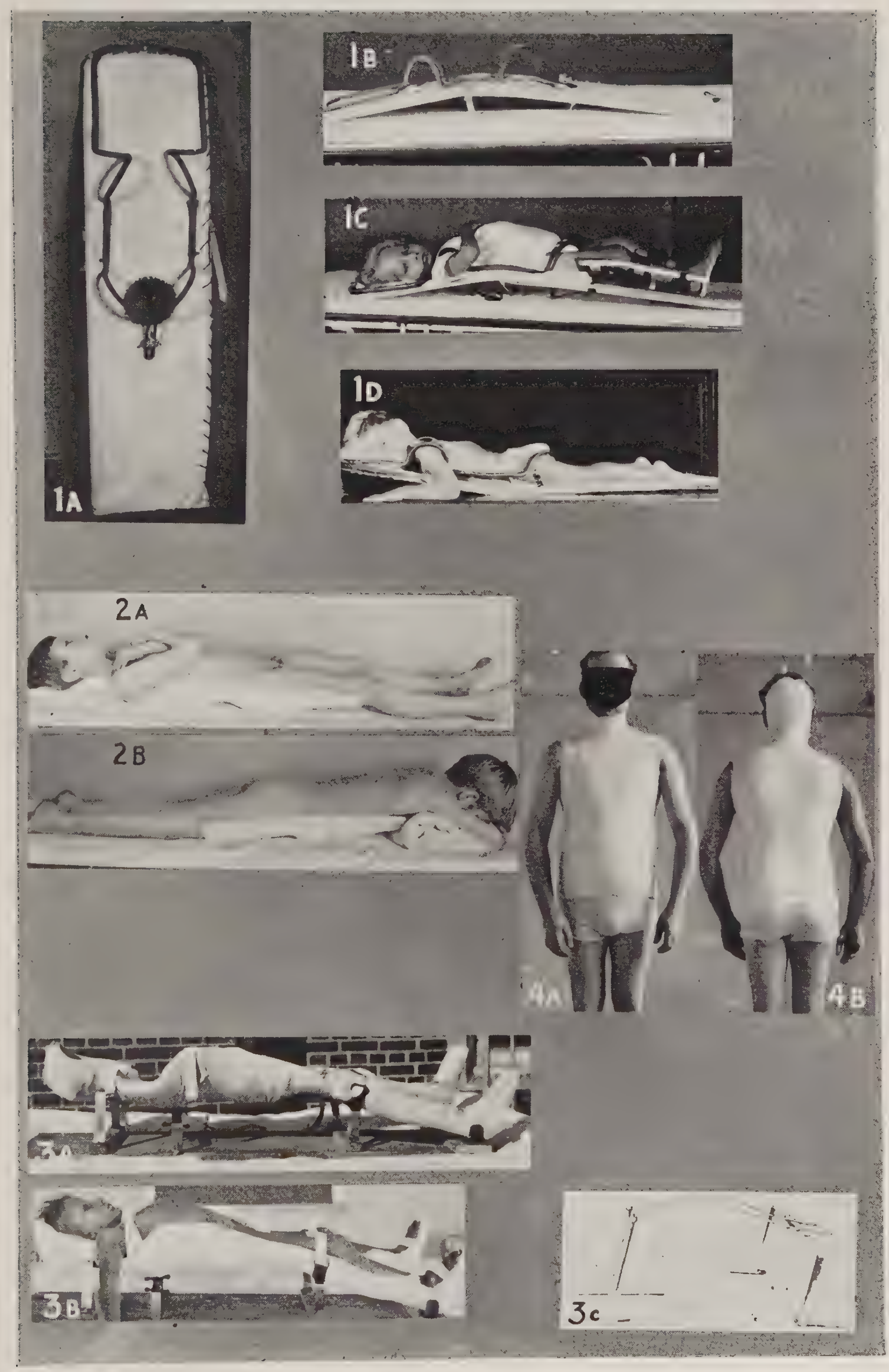


PLATE LXI

apparatus or braces actually fail in relieving the superincumbent weight. Horvath[93] found that in order to relieve the 3rd lumbar of weight-bearing a backward inclination of the superincumbent body of 20 degrees would be necessary; in order to relieve the 1st lumbar a similar inclination of 25 degrees, and for the relief of the 9th dorsal an inclination of 30 degrees would be required. Such a degree of reclination cannot be produced, however, except by extreme lumbar lordosis which is not tolerated by the patient. It appears, therefore, from experimental evidence as well as from clinical experience that a sufficient reclination of the body to the point of actually relieving weight-bearing cannot be accomplished in ambulatory position.

8. *Duration.*—How long is the recumbent treatment in frame or plaster bed to be continued?

It must be continued until the acute stage is past, until the fever has disappeared for a certain length of time and until there is no pain, and no development of abscesses, until there is no sign of spinal compression and until the general condition of the patient is satisfactory and until the local examination of the spine shows a sufficient degree of consolidation. This, in children may be a matter of two or three years, but, as a rule, in uncomplicated cases, twelve to eighteen months of recumbency are sufficient, and occasionally a period of six months to a year may lead to a satisfactory stage of recovery so that ambulatory treatment can then be taken up.

(9) *The Social Problem of Recumbency Treatment.*—That recumbency treatment in combination with general regime is by far the safest method to be applied in the first and second years of the disease has already been pointed out. The long duration of this treatment, however, involves a number of important problems of sociologic character, principally due to the necessity of prolonged hospitalization to which few institutions only are able to do full justice. For these the solution lies in the establishment of country homes with proper medical and nursing supervision.

(10) *Home Care.*—Because it is economically impossible to provide full institutional treatment, even for a larger portion of patients suffering from spinal tuberculosis, the practitioner should give fullest consideration to the possibilities of home treatment for recumbent patients. Here, the purely orthopedic side of the management will appear simple in comparison with the problems of sociologic and economic nature. The latter requirements draw heavily upon the resources of the home, but they are entirely feasible with proper organization.

Three things must be provided: (1) sufficient nursing under proper medical supervision; (2) education, and (3) recreation.

Nursing.—When home nursing cannot be carried out by a professional nurse, it is of the greatest importance that the attendants and friends of the patient be instructed by the supervising physician. The position of the patient in bed protected by air and water cushions, the arrangement of the proper recumbency, the supervision of the mechanical appliances, the careful recording of temperature and weight charts, and of the patient's condition in general, can be carried out under the eyes of the attending physician if he is willing to impart careful and detailed instructions to the family of the patient. It is the custom in the writer's clinic to require of patients or of parents the keeping of temperature and weight charts and to note the fluctuation of appetite. They are instructed in details of appropriate diet and they are taught to appreciate the importance of elimination. They must understand the method as well as the danger of insolation and they are given an insolation chart by which the dosage of exposure can be regulated.

Education.—When bedside teaching as practiced in many institutions is properly carried into the home, one of the greatest arguments against the recumbency treatment, namely, that it deprives the patient of educational advantages will fall. With modern educational methods this bedside teaching is quite feasible and it can be combined with recreational work.

Craft and Recreation.—The occupational therapy with its educational activities is able to do a great deal for the mental and moral uplift of the patient; it also brings out natural inclinations and propensities. It produces skill and experience and enables the patient to face more confidently the future problems of self-support.

b. The Ambulatory Treatment.—In principle the ambulatory treatment pursues the aim to eliminate motion of the spine as completely as possible by the application of a rigid contentive apparatus, be it a plaster device or a brace.

Weight-bearing is not eliminated thereby unless the wearing of apparatus is combined with recumbency treatment.

(1) *Indications.*—When the acute stage of the disease has passed and the conditions which were mentioned before as indications for recumbency treatment no longer obtain, the ambulatory treatment may be instituted on the grounds that elimination of weight-bearing is now no longer an absolute necessity and that elimination of motion of the spine is sufficient to sustain the process of repair. Therefore, the indication for this type of treatment is made by exclusion, viz., of all such conditions as require recumbency.

(2) *Mechanical Principles of Elimination of Spinal Motion.*—From the mechanical point of view the problem of supporting the spine is simple. It is to be protected against the inclinatory forward movement which produces the gibbus. Immobilization is effected upon the principle of support with three points of application: one at the gibbus and two counterpoints in front, one at the shoulder girdle, the other at the pelvis. Accordingly, plaster casts and braces are generally constructed on the plan to give support to the spine in the back and to be braced in front against two fixed points: a point at the shoulder girdle and a point at the pelvis. For mechanical reasons it is obvious that such an apparatus must have, above all things, a firm base.

For all tuberculous foci located at the mid-dorsal and lower dorsal sections, the pelvis will be sufficient support provided that the apparatus is closely molded into it and that it fits firmly over the bony prominences.

If the site of the gibbus is higher than the 7th or 8th dorsal, this arrangement becomes inadequate, bcause the cervical spine is able to transmit motion to the upper portion of the dorsal spine, which, therefore, is no longer controlable by the dorsal support. In this case the support of the spine must be extended upward to include cervical spine as well as chin and occiput as stable points.

On the other hand, if the site of the disease is lower than the 11th or 12th dorsal, then the arrangement of pelvic support likewise becomes inadequate, because, here again, the lumbar spine is insufficiently immobilized and movement of the pelvis transmits itself to the site of the disease without sufficient check. Therefore, any disease situated in the upper dorsal region requires the extension of the retentive apparatus to head and chin, and any disease lower than the 11th and 12th dorsals requires the extension of the apparatus to the pelvis and the thigh.

(3) *The Plaster Jacket (Plate LXI, 4a, b).*—The plaster jacket was introduced into the treatment of tuberculosis of the spine in 1875 by L. A. Sayre[169, 170] and it has since occupied a prominent place in the ambulatory treatment of this condition. The jacket is applied in suspension of a degree compatible with the comfort of the patient.

Here, the question presents itself: what is the *effect of suspension upon the gibbus deformity?*

Anders[10] (1889) investigating this point, accurately measured the effect of longitudinal traction, both in the cadaver and the spondylitic patient. He found that the posture of the spine as a whole received a change of relation to the line of gravity and that a compensation of the spine takes place to either forward or backward inclination. If the line of gravity is directed forward by the deformity, then under suspension it moves duly backward and vice versa, in hyperextension deformity it is placed forward. This means, that suspension produces its immediate effect not so much upon the gibbus itself but upon the free portions of the spine above and below, and it, therefore, contributes to the formation of compensatory curves. It appears, then, that the suspension position in the syondylitic spine marks the most appropriate position for the relief of weight-bearing, though too incomplete to actually eliminate it; it is the most suitable position for immobilization, and it produces an effective compensation of the spine in its free sections.

Strong traction to an extent equal to the body weight is entirely irrational and unnecessary.

The Technic of Application of the Plaster Jacket.—The body is protected by stockinet and the bony prominences are covered by pieces of felt placed over the sacrum, the anterior spines of the os ilei, the upper portion of the sternum, over the gibbus, and in parallel strips over both sides of the involved region to protect it from friction and to provide greater support.

For the upper dorsal disease a head support is required as explained before. This may be accomplished by either including the head into the plaster support, or by extending the plaster to chin and occiput, or by the use of a jury-mast. A jury-mast is a posterior upright curved to the back of the head and to the cervical spine and embedded into the cast. On the upper end it carries a sling in which chin and occiput are held suspended. Instead of this rather cumbersome and unsightly arrangement, it is better to embed into the plaster a ring reaching around chin and occiput, and arranged to swivel in the upper end of an upright, the base of which is incorporated into the body cast. The extension of the plaster jacket under the chin and occiput often causes a recession of the chin in younger children, a retrognathia, with malocclusion of the teeth.

The Application of the Plaster Jacket in Recumbency Position.—One of the best means to secure the proper recumbent position for the application of the jacket is the so-called Goldthwaite frame (Plate LXI, 3c). This is a portable frame placed upon the table with two parallel steel bars fitted to the contours of the spine. These steel bars rest upon a post at one end and upon a bridge at the other. Such a contrivance may also be fastened to a Bradford frame and the plaster cast be applied upon it. By attaching a ratchet to the ends of the frame, the position can be conveniently combined with traction.

(4) *Retentive Braces.*—A most efficient and simple brace for spinal disease which embodies the principle of anteroposterior supports as explained above, is that of C. F. Taylor, known as the Taylor brace (Plate LXII, 1). It consists of two posterior uprights with a bottom piece and a top piece attached to it. The bottom piece is made in the shape of an inverted ''U'' and attached to the lower end so that the transverse part of the ''U'' crosses the uprights while its free ends terminate in small discs about one inch above the tuberosity of the os ischii. The upper crosspiece is fastened at the level of the shoulder and curves forward over the shoulders to the anterior edge of the trapezius. To secure counter pressure in front a heavy canvas apron is attached to horizontal bars which cross the posterior uprights at different levels, and the angulated anterior ends of the upper crosspiece carry shoulder straps which run from the anterior ends of the crosspieces over the shoulders and cross in the back. Proper provision is also made to attach to this brace a head piece in case of cervical or cervico-dorsal disease. This head piece consists of a ring encircling chin and occiput and it is fitted adjustably into a post behind, the lower end of which, again, is fitted to the body part of the brace. It can be made to slide up and down so that the neck piece can be regulated at required length and held there by set screw.

The author's standard body brace (Plate LXII, 2a, b) is constructed along similar principles. It consists of a pelvic girdle fashioned after the Hessing type of pelvic frame and encircling the iliac crest. The body frame consists of two strong uprights in the back fitted to the spine and two uprights in front running from the pelvic ring upward. Above, all four uprights are fastened to the shoulder girdle piece of the frame. This piece crosses the vertical upright in the back at right angles, curving downward under the arm and again upward

PLATE LXII

Fig. 1.—The Taylor spinal brace. (After Taylor.)

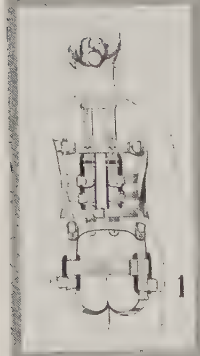
Fig. 2.—Author's standard body brace (front and back views).

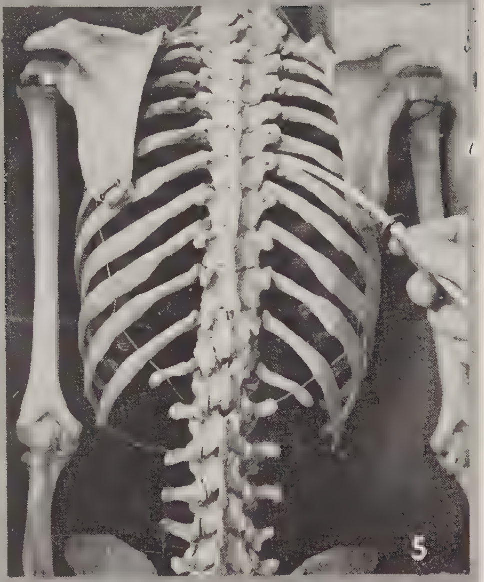
Fig. 3.—Celluloid jacket for combined curvature.

Fig. 4.—Wullstein frame for application of cast in sitting position.

Fig. 5.—Puncture of mediastinal abscess by trocar (technic of Valtancoli).

Fig. 6.—Costotransversectomy showing stripping of laminae and transverse process. (Parts to be removed indicated by dotted line.)





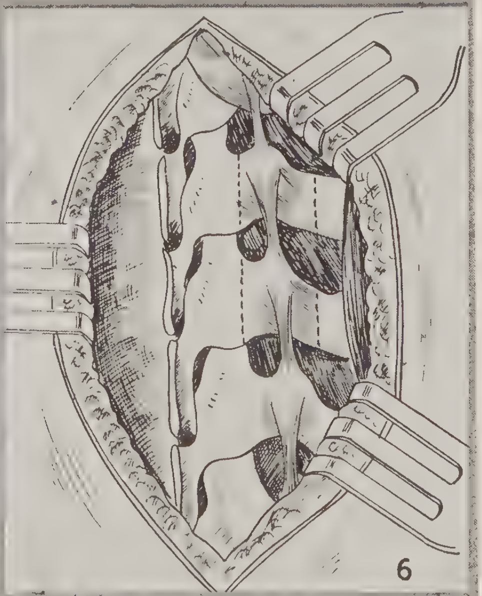


PLATE LXII

in front, receiving the frontal uprights and ending in small discs somewhat inward to the shoulder joint articulation. Shoulder straps secure the shoulders, and the anterior uprights are drawn together in front by means of straps and buckles.

Nathan's[131] spinal brace consists of two uprights and two pelvic bands and shoulder straps similar to the so-called spring back brace (Plate L, 2, 3). A great number of braces of different types are used, and all avail themselves of the three-point principle of support. Very good and sufficient braces can be manufactured inexpensively from celluloid. Celluloid braces are made from celluloid dissolved in acetone which is painted in successive layers on gauze bandages or stockinet. These layers are allowed to dry, one by one, and steel strips are placed between them. These jackets may be padded with chamois leather and then bivalved, lacings being attached to the anterior and posterior halves, or they are laced or buckled in the front (Delitala[55]). (Plate LXII, 3.) The celluloid jackets have the advantage of being inexpensive, very light, and comfortable, especially if perforated for the circulation of air. They do not, however, have the durability of the steel apparatus and they are inflammable.

(5) *Corrective Treatment in Plaster Jackets.*—When Sayre introduced his plaster jacket in 1875 he made an attempt to correct the gibbus by gradual suspension. In the reclination plaster bed of Lorenz there is also an attempt made to exert pressure upon the gibbosity with the object of correcting or improving the deformity. It was Calot,[38, 39] however, in 1896, who made the first attempt of forcible redressment under anesthesia. Several assistants pull upon head, arms, and lower extremities, and then a great deal of pressure is applied directly upon the gibbus. In its extreme radicalism this maneuver, however, proved to be so hazardous and dangerous that it has been generally abandoned. It appeared that correction of the gibbus deformity even in suitable cases could not be carried out without much risk to the patient. Among six hundred and ten cases reported in the literature, Bradford[32] and Cotton reported twenty-one cases of death immediately after operation. Menard[128] in 1897 demonstrated upon an anatomic specimen the effect of forcible redressment of the gibbus in tuberculosis of the spine. He showed that the cord and the meninges remained intact, showing neither tear nor contusion, but the vertebral segments were separated up to 8 cm. Brun[34] also reports a case of a patient who died after forcible redressment, and in whom the autopsy showed cavities formed by the separated bodies of the involved vertebrae measuring 8 to 10 cm. At the bottom of these cavities the meninges and the cord also had remained intact. The vast cavity formed was filled with detritus granulations, sequestra, etc.

The repair of such a cavity would be very doubtful. As a matter of fact, such a redressment could only retard the cure, even though its corrective effect is, without doubt, much more marked than that of any other method.

Whatever correction is obtained from methods which are current today, is due largely to compensatory curves above and below the diseased portions of the spine. One now produces a gradual correction in all ankylosed cases by corrective jackets applied either in recumbency or in suspension. Goldthwaite's[77] frame is admirably suitable for the application in recumbency; in suspension, the jacket may be applied with the patient sitting or standing. In the sitting position corrective jackets with compensatory curving of the adjacent portions of the spine are best applied in Wullstein's[211] frame (Plate LXII, 4) and in the standing position in the frames of Schanz and Schulthess.

c. Treatment of Abscesses.—Spondylitic abscesses in general are objects of conservative treatment and should keep their subcutaneous characters by all means and as long as possible. Absorption under the treatment of rest and recumbency may be expected in a large majority of cases. Nevertheless, abscess formation in general represents the most serious complication of spinal tuberculosis. As long as the abscess remains subcutaneous septic infection of a tuberculous character can only occur through the blood stream, which is a possible but not a probable occurrence. Some cases of hematogenous infection with bacterium coli have been observed.

(1) *Puncture.*—Once the abscess communicates with the outside, however, it must ultimately change into a septic one, and for this reason the distinction between closed and surgical tuberculosis of the spine, that is, one with or without communicating abscess is of great importance for the prognosis. Under the general rule, intervention in tuberculous abscesses is, therefore, refrained from, unless they assume a superficial character or threaten with perforation. This occurrence should be prevented by the puncture of the abscess. The puncture is carried out by introducing into the cavity a trocar under special aseptic precautions and in a manner which will prevent the development of a direct channel of communication. To effect this, the trocar is introduced in an oblique direction away from the point of the abscess which threatens to perforate, so as to make the canal as long and as oblique as possible in the subcutaneous tissue. Then, when the abscess is evacuated—facilitating this by gentle pressure at the periphery of the abscess—the trocar is withdrawn, the abscess is sealed, and a dressing of dry gauze is applied. Great care must be taken to insure absolute cleanliness and asepsis. In the course of time the abscess refills and then the maneuver is to be repeated. When the abscess contents appear too thick so that evacuation by aspiration becomes impossible, a short incision may be made and the abscess cavity emptied of its semi-fluid contents; after this it must be carefully sutured and covered with sterile dressings.

(2) *Injection of the Abscess With Modifying Fluids.*—The use of antiseptic remedies for the abscess cavities was introduced by Billroth and Miculicz. It is based upon the favorable influence of iodoform in tuberculosis of bones and joints. A considerable percentage of abscesses was found to heal under this treatment, and iodoform in a 10 per cent glycerin emulsion has come into general use.

According to the age of the individual and the size of the abscess, as well as the number of succeeding injections, up to 50 to 100 grams of the solution may be injected. With this treatment the contents of the abscess change quickly from a thick pus to one of more liquid and mucous character.

Iodoform in form of idoform oil was introduced by Bruns.[35]

Careful dosage of iodoform-glycerin and watchful supervision is necessary. Cases of iodoform intoxication have been observed within 24 hours after injection; its signs are: rise in temperature and pulse, hemiglobinurea and other severe kidney changes.

The Modifying Fluid of Calot.[37] Calot uses as modifying fluids emulsions consisting of oil-creosote and iodoform injected in doses of 2 to 12 grams according to the age of the patient. The number of aspirations and injections are from 10 to 12; they are continued until the fluid withdrawn is serous in character.

Formula:

Sterilized Oil	70 grams
Ether	30 "
Creosote	6 "
Iodoform	10 "

The employment of iodoform in suppurating glands of the neck, or in distant gravitation abscesses in Pott's disease is to be avoided.

Another type of modifying fluid introduced by Calot is the glycerinated naphthol camphor.

Naphthol Camphor	2 grams
Glycerin	12 "

To be shaken vigorously for 1½ minutes and injected immediately.

(3) *Operative Treatment of Abscesses.*—

(a) The Retropharyngeal Abscess.—If this abscess is obstructing breathing and deglutition, it demands prompt evacuation. In case of emergency this may be accomplished by an incision in the midline of the posterior pharyngeal wall. The routine evacuation, however, should be made at the side of the neck, entering through the vaginal fascia and following the anterior surface of the scaleni. One finds the abscess just behind the prevertebral fascia which is bulging forward.

(b) Cervical Region Abscesses.—These point to the lateral triangle of the neck and can be approached by the same route.

(c) Upper Thoracic Region Abscesses.—In some instances these abscesses cause pressure upon trachea and bronchi with spasmodic attacks of dyspnea often misdiagnosed as asthma, and demand speedy evacuation. For the lower cervical and upper dorsal spine the route already described is suitable.

(d) The Retromediastinal Abscess.—Because this type of abscess represents one of the severest complications in Pott's disease it merits special attention.

A description of the anatomic relation between abscesses and fascial planes, and of the migration of the dorsal abscesses into the retromediastinal space has already been given. Such an abscess becomes dangerous mostly by pressure against the contents of the retromediastinal space, and because of the possibility of perforation into neighboring organs, such as pleura, pericardium, etc. Still more often the abscess becomes serious by establishing direct communication with the contents of the spinal canal. Then it is instrumental in the production of a most persistent and unmanageable paraplegia. Not less than fourteen out of twenty-three cases of mediastinal abscess observed by the writer[182] showed definite paraplegia due to extension of the abscess, or of tuberculous granulation tissue into the canal with subsequent pressure upon the cord. Severe paraplegia, however, is not the only emergency symptom in retromediastinal abscess. In a number of cases the pressure produces embarrassment of pulmonic and cardiac functions. If the abscess is accessible enough and if its contents are sufficiently liquid, it can be treated by puncture or aspiration as advocated by Sgalitzer[177] and Calvé.[40] Valtancoli[195] uses a trocar in all cases of paraplegia in tuberculous spondylitis in which the radiograph shows the presence of a mediastinal abscess accessible from the outside, by puncture or aspiration. Such an indication exists, also, in cases in which there is no manifest paraplegia but in which premonitory symptoms such as weakness of the lower limbs, increasing tendon reflexes, foot clonus, etc., have made their appearance. Valtancoli describes the technic as follows: an anteroposterior and lateral picture is made before operation after ingestion of bismuth so that the outlines of the esophagus are defined and the space between it and the spinal column denotes the situation of the abscess. Then a trocar not less than 9 cm. long is introduced through the intercostal space into mediastinum giving it a slanting direction toward the midline and letting it follow closely the contour of the vertebral body. It is held close to the upper border of the ribs so as to avoid injury to the intercostal nerve and vein (Plate LXII, 5). The inner diameter of the cannula of the trocar should be not less than 3 mm. or ⅛ inch. A similar technic is used by Schede:[171] the puncture needle is inserted 2 cm. to the side of the spinous process at a level corresponding to the most distended part of the abscess. Pus is usually found at a depth of 6-9 cm. as demonstrated roentgenologically (Staub).

Prevertebral abscesses of the lumbar spine are not so well adapted to puncture because they gravitate downward toward Poupart's ligament. Cases are reported by Dollinger[57, 58] in which a prevertebral abscess situated at the 3rd and 4th dorsal level and causing symptoms of cord compression, spastic paralysis, etc., was treated by repeated puncture; eight in one, and six in another case with relief of symptoms; 20 c.c. of pus being removed at each puncture.

Costotransversectomy.—In many instances the symptoms of mediastinal abscess are so threatening that the indication arises for more radical procedures. The operation best applicable to this condition is the costotransversectomy.

This operation was first performed for tuberculosis of the spine by Menard[126] (1895), after it had previously been applied by Heidenheim for osteomyelitis. It is superior to simple aspiration because it gives a much better outlet to the thick and creamy pus. Menard operated upon twenty-four cases with good results in nineteen, and Bastianelli[19] was able to collect from the literature forty-one cases with thirty-two cures. The disadvantage of this method is that a sinus often becomes established. It is no doubt a most effective means of combating the paraplegia caused by the retromediastinal abscess. The operation consists in the resection of the lateral ends of the transverse processes with the attached ends of the ribs. One first makes the approach by stripping the laminae and neural arches as is done in the method of Hibbs; then one resects the lateral half of the transverse process and follows it by resection of the head and neck of the rib (Plate LXII, 6). The operation requires a great deal of care as the lungs and pleura might easily be injured. The writer[182, 183] has used this method in five cases, in three of which the drainage was successful, and a considerable amount of pus was evacuated. Two of the three cases recovered with disappearance of paraplegic symptoms. Of the two other cases in which pus was not evacuated, one made almost complete recovery from paraplegia while in the other there was no improvement during the time of observation.

(e) Transperitoneal Drainage. Drainage of the Abscess in the Retroperitoneal Space.—The abscess which develops from the lumbar spine, the sacrum, or from the sacroliac articulations accumulates in front of the sacrum or the 5th lumbar vertebra.

For the closed retroperitoneal abscess the rule applies that it is to be treated conservatively. The perforation of the abscess and the establishment of a sinus, however, create a special condition which usually demands definite and energetic surgical procedures. As early as 1893 Drs. Ridlon and Jones[570] describe the evacuation of an abscess situated in the retroperitoneal space in front of the lumbar spine. This abscess was reached by incision along the erector spinae mass exposing the quadratus lumborum and proceeding to the anterior surface of this muscle. The abscess could be felt by the finger passed under the transverse process toward the body and fluctuation could be made out by pressure.

When a large retroperitoneal abscess exists and becomes fistulous, the subsequent pyogenic and septic changes are responsible for a high mortality, therefore, energetic surgical procedures for complete evacuation of the abscess are justified.

In two cases the writer[182] approached a prelumbar retroperitoneal abscess from the lateral border of the erector spinae muscle, dissecting through the muscle mass into the retroperitoneal space and establishing wide drainage.

Jourdan[571] finds that the indication for transperitoneal drainage in adult tuberculosis of the three lower lumbar or two upper sacral vertebrae exists very frequently, and one should not hesitate to establish prompt and sufficient drainage.

(f) Sacral Abscess and Transsacral Drainage.—In cases of presacral abscess the drainage must often be established through the sacrum by resection of the sacroiliac articulation, including portions of the os ilei and of the sacrum. This type of retroperitoneal drainage is especially indicated in sacroiliac disease. It should be undertaken in case of septic infection, and before the pus has finally gained the pelvic floor and fistulae have become established at the inner side of the thigh, or posteriorly in the neighborhood of the tuber os ischii.

For the drainage of these abscesses the technic of Picqué[146] is to be recommended (Plate LXIII, 1). The sacroiliac joint is exposed by a curved incision made along the posterior border of the iliac crest and continuing downward along the outer border of the sacrum. The periosteum and the overlying fleshy parts are detached from the bone until the entire posterior portion of the os ilei is bare and stripped from the posterior superior spine downward. When this is done one may then, with a broad osteotome, easily divide the crest of the os ilei from the posterior superior spine downward to the upper corner of the great sciatic notch. By removing a corresponding piece of the sacrum a good drainage of the retroperitoneal cavity, lying in front of the sacrum, may be obtained.

The writer[182] has performed this operation in five cases; in two of them the progress of the septic condition could not be checked, although a wide communication was established and drainage became profuse; but in the other three cases the drainage proved sufficient to control the septic condition.

d. Operative Treatment of Compression Paralysis: Spinal Decompression.—

(1) *Indication.*—Laminectomy is indicated in tuberculosis of the spine when the conservative treatment fails to relieve the compression paraplegia. If an abscess in the retromediastinal space can be assumed to be responsible for the compression symptoms, then the above-mentioned methods of drainage of the abscess are given first consideration. One should remember that in the majority of cases paraplegia recovers under prolonged recumbency and traction. It is, therefore, only a small minority in which decompression by laminectomy becomes necessary.

As a rule the indication for this operation is made only after a long and patient attempt to relieve compression symptoms by conservative means. Occasionally, however, one must act quickly, for instance, in the rare cases in which the spastic character of the paralysis suddenly changes to the flaccid type, or in cases in which there is evidence of sudden collapse with bony pressure against the spinal cord. It has been claimed that light paraplegias are influenced by operative fusion (see later) of the spine, but it is doubtful whether the fusion has any direct effect upon it. It is more likely that the recumbency associated with such an operation exercises a beneficial effect upon the compression symptoms. An absolute indication for laminectomy exists also in the rare cases of exuberant new bone formation at the seat of repair and subsequent bony pressure upon the spinal cord; also in cases with definite bony fusion of the spine, not yielding promptly to traction and recumbency (Borchers[27]).

Several observers (Vulpius, Debrunner,[52] and Gaenslen[67]) recommend the combination of laminectomy with the fusion operation of the spine.

PLATE LXIII

Fig. 1.—Picque's technic of sacroiliac drainage.

Fig. 2.—Laminectomy. (After Elsberg.)
(A) Removal of spinous processes.
(B) Removal of laminae.
(C) Resuturing of dura where incision was required.

Fig. 3.—Hibb's technic. (Reaming out of articulations.) (After A. Steindler, operative orthopedics.)

Fig. 4.—Hibb's technic. (Production of bone bridges by operative destruction of laminae and spinous processes.) (After A. Steindler, operative orthopedics.)

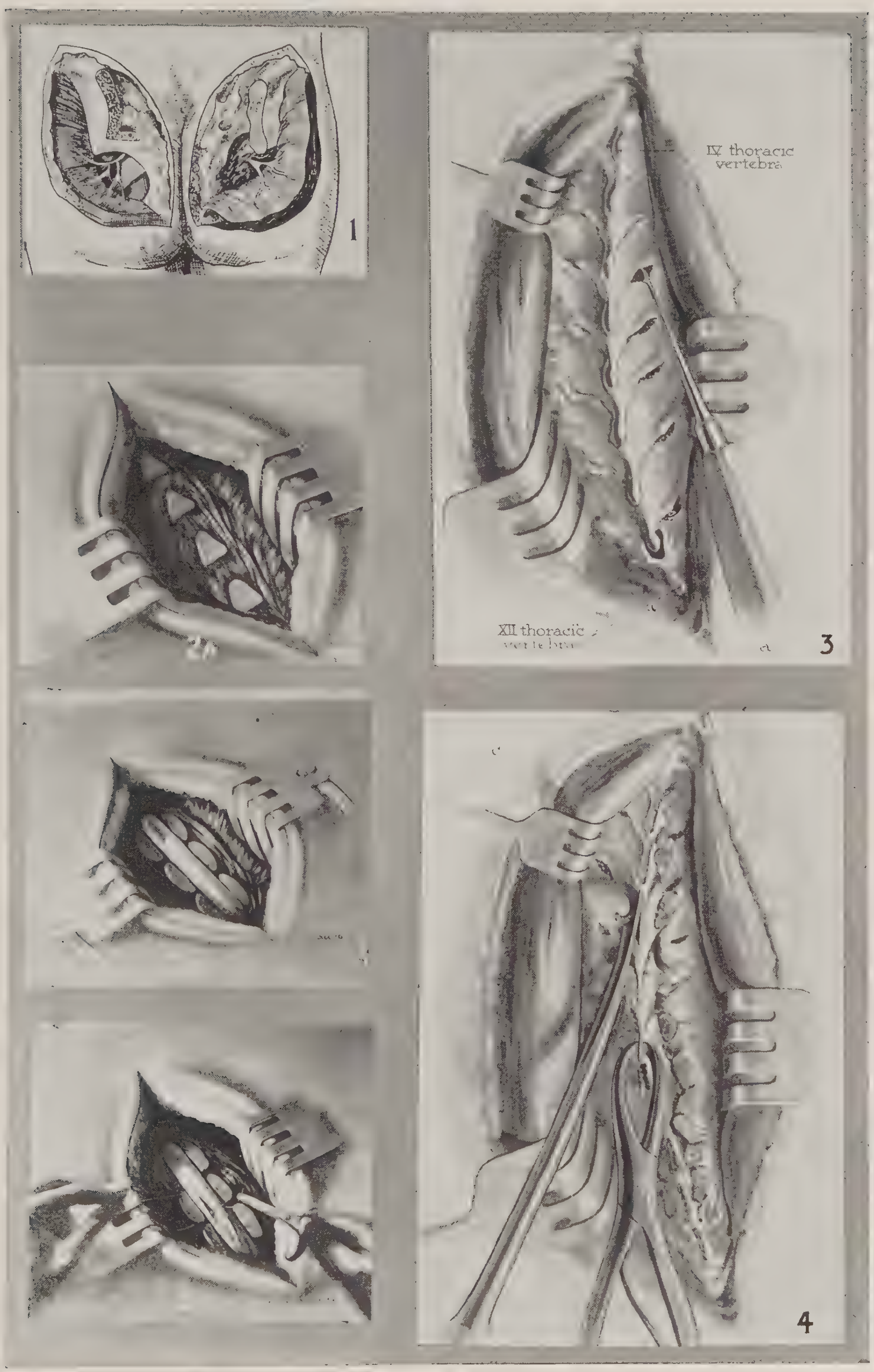


PLATE LXIII

(2) *The Technic of Laminectomy (Plate LXIII, 2a, b, c).*—The neural arches of the laminae are exposed by subperiosteal dissection until the bases of the transverse processes are laid bare. Then all bone is removed by the rongeur as far laterally as the articular processes. Close attention must be paid to the first appearance of the dura mater and great care must be taken not to injure it. The cavity is packed with hot sponges in order to control completely the oozing from the bone. If decompression alone is contemplated, and this is most frequently the case in Pott's disease, there is no need of opening the dura.

(3) *Statistics.*—Experiences on the results of laminectomy for the relief of cord compression in tuberculosis of the spine vary widely. The largest series, reported by Denk,[576] gave discouraging results and the majority of his patients ultimately succumbed. But it must be considered that laminectomy, even though it is the last resort, must be undertaken at the right time and the indication must be made before degenerative changes have taken place. After this, nothing can be expected from the operation, and it is unwise to wait until the full development of the flaccid type of paralysis. In several cases in which laminectomy was performed by the writer relief was obtained. In one case a patient showing signs of spasticity at entrance, a fusion operation was performed for the relief of a middorsal tuberculous spondylitis. One month after the operation, while the patient was fully convalescing, the spasticity suddenly increased at a rapid gait and changed to flaccid paralysis within a few days. In this case a laminectomy brought ultimate relief to the patient and six months after the operation she was able to be up. No sign of return of function appeared, however, until the end of the first month after laminectomy. (For statistics on laminectomy performed for compression paralysis from other causes, see Chapter IV).

e. The (Palliative) Operative Treatment for Tuberculosis of the Spine; Fusion Operations.—On the merits of operative measures for the stabilization of tuberculous spine, and especially on the selection of cases suitable for surgical interference, there is a wide divergence of opinions. It seems to us that a problem of such weight, as is the operative treatment of spinal tuberculosis, requires that all arguments, for and against, be given a hearing so that, upon sifting the accumulated evidence, the reader may arrive at a sane and impartial judgment of his own.

Operative treatment of spinal tuberculosis by fusion of the vertebrae is a palliative method. It does not touch the seat of the disease and cannot claim to have a direct influence on the course of tuberculous changes within the vertebral bodies. It does claim, however, to affect a complete, reliable, and permanent immobilization of the spine by internal splinting.

(1) *Indications.*—The indications for fusion operations of the spine in tuberculosis are to be considered from the following points of view:

(a) Adults and Children.—The majority of opinions incline to the view that fusion is frequently indicated in adults, but only exceptionally in children. The reasons for restricting the indication in children are:

1. The tendency to natural bony fusion of the spine is much greater in children than in adults. In the latter healing by bony fusion is the exception, and healing by fibrous union is the rule.

2. Recumbency is the safest treatment in tuberculosis of the spine and is the more appropriate in children since the advantages of sunlight and fresh air treatment as well as that of education and recreation can be combined with recumbent treatment.

The argument that time means less to children than to adults can be dismissed as thoughtless and unconvincing.

There are, however, certain conditions in which the operation is definitely indicated in children. First of all, older children and all children in whom symptoms of spinal compression develop in spite of recumbency, should be considered for fusion of the spine. Operation may also be taken into consideration in children when the disease is located in the upper dorsal or in the lower cervical regions, where it is difficult to obtain sufficient immobilization in recumbency and almost impossible in ambulatory treatment without inclusion of chin and head.

(b) Early or Late.—Another point to be decided is whether the operation should be performed early or late in the course of the disease. There is a report at hand from Allison and Hagen[9] which considers this point.

Dividing their cases in (a) those operated at early stages in which there was no deformity and no complication; and (b) those already showing marked deformity with persistence of more or less acute symptoms but no other complications; and (c) those operated in the presence of complications, such as psoas and lumbar abscess, tuberculosis of other joints, pressure paralysis, or pulmonary tuberculosis, they found that the group operated upon at early stages with no deformity and no complications, showed the best results, the patients going on to complete recovery. In the group operated on later the results were fairly good; and they were least satisfactory in the group including cases which showed complications such as abscesses, pulmonary tuberculosis, or pressure paralysis. This difference, of course, has its reason in the nature and stage of the individual case, but it shows, also, that abscess formation, while it is not a contraindication for the operation, is, on the other hand, not particularly influenced by it; the same may be said of compression paralysis, except in some cases where recumbency alone has proved insufficient to provide the necessary immobilization of the spine. It follows, then, that stabilizing operations should not be indicated, as is often done, on the grounds of abscess formation or compression symptoms alone.

The indications may be summarized as follows: In children, exceptionally, namely, in high localization (cervico-dorsal or high dorsal) and in the presence of compression symptoms not responding to recumbency, but not requiring laminectomy.

In adults, more generally, especially if the disease is located in the lower dorsal or lumbar spine. Here, it may almost be made the rule, subject only to

PLATE LXIV

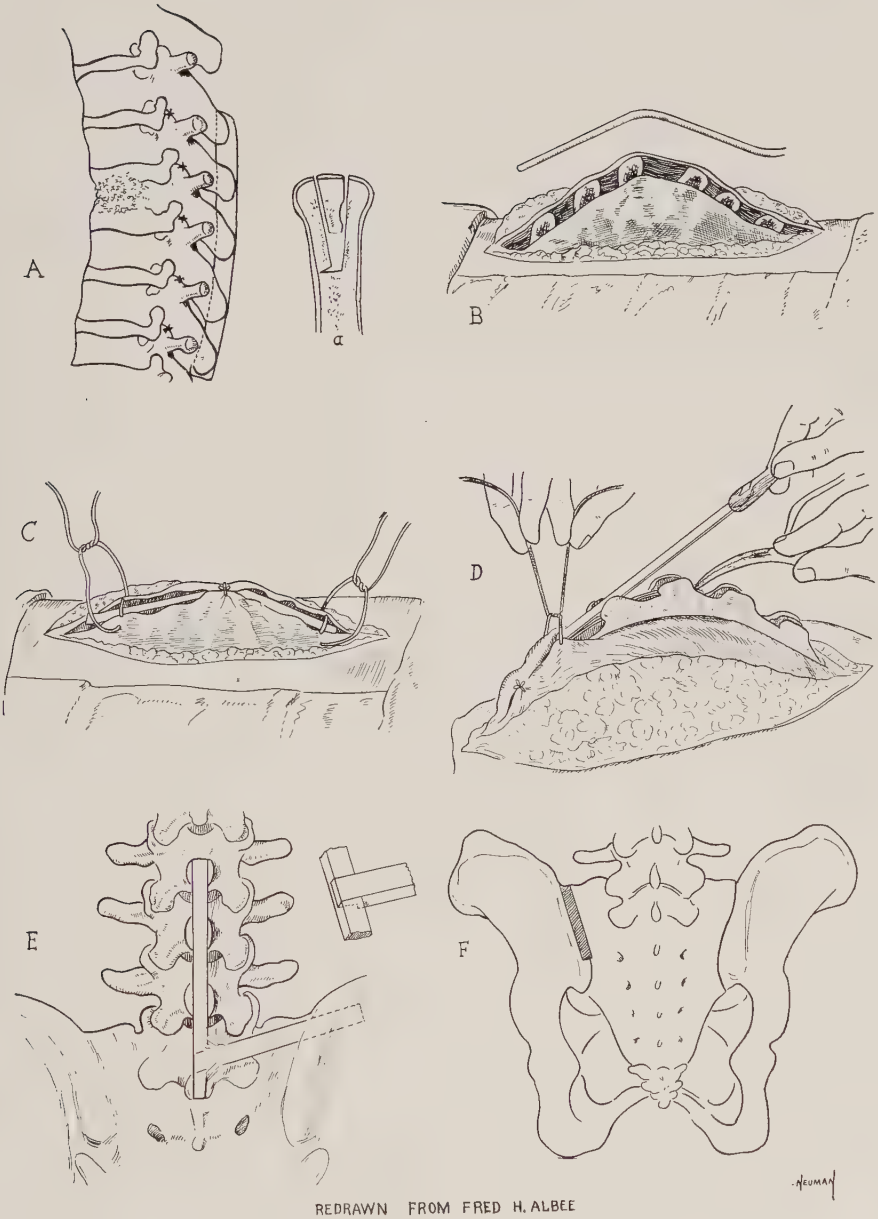
ALBEE TECHNIC FOR SPINAL, SACROILIAC AND SACROLUMBAR FUSION

Fig. A.—Diagram of operation.

Fig. B.—Preparing of bed and measuring of graft.

Fig. C-D.—Placing of graft and suture.

Fig. E-F.—Albee's technic for sacroiliac and sacrolumbar fusion.
  (E) Combined inlay graft for sacrolumbar and sacroiliac fusion.
  (F) Inlay graft for sacroiliac fusion.



REDRAWN FROM FRED H. ALBEE

PLATE LXIV

restrictions pertaining to the general health of the patient, especially to the condition of the lungs, or to other complications which might increase the operative risk.

As to the stage of disease in which operation should best be performed, whether early or late, the majority of opinion inclines toward early operation. There are, however, objections raised by some against operating before bony repair is definitely established. (See Critique of Fusion Operations.)

2. *Technic.*—Fusion operations of the spine were instituted many years ago by Lange and others. Lange[111, 112] first conceived the idea of wiring the spinous processes together. In his original procedure he used steel wire, 10 cm. long and 4 mm. thick, placed upon both sides of the spinous processes under the musculature, and fastened to the spine by strong ligatures. Later the wire was substituted by celluloid rods placed parallel to both sides of the spine and likewise secured by silk thread sutures. Objections were soon made to the implantation of foreign material and one began with the implantation of autogenous bone graft. Some do not accept these objections against foreign body implantation, believing that this disadvantage is offset by the greater precision and accuracy of splinting afforded by celluloid rods (Baeyer[21]); they do not break, and they remain unchanged at the site of implantation. Especially for children with cartilaginous spines this substitution of the autogenous bone by celluloid graft is recommended. Today, the original method of Lange is rarely used, though its technic is simple. It consists in the denudation of the spinous processes and the neural arches and the apposition of celluloid splints fastened through little drill holes to the spinous processes and also to the interspinous ligaments by means of silk sutures. The possibilities of better adaptation of celluloid rods to the deformity, especially in the dorsal spine, the easier handling of the rods, and their durability, constitute certain technical advantages.

Because of the objections raised against the implantation of foreign and unabsorbable material, Lange's method never gained general recognition. The modern methods of spinal fusion adopt the autogenous bone implantation, relying either upon ultimate absorption and the substitution of the graft by new formed bone from the host, or else upon direct fusion of living bone material recovered from the host. The first of these principles is embodied in Albee's, the second in Hibb's technic of spinal fusion.

The Technic of the Albee[1, 2, 4, 5, 6, 7] Operation (Plate LXIV, A, B, C, D).—In the operative plan of Albee the incision is made over the spinous processes; the dorsal fascia and the spinous ligaments are split, especially over the tips of the processes, and the ligamenta interspinosa between them. Then the spinous processes are cut in half by driving a chisel into them for a distance of ½ to ¾ of an inch. A graft, carefully measured for its length from the bed prepared in the spine, is then cut from the crest of the tibia with a twin-saw, leaving the periosteum intact. This graft is inserted between the split halves of the spinous processes.

Modifications of Albee's technic have been suggested: one is the use of beef bone instead of the living graft, or as additional and in stabilization. L. A. Brown,[33] reporting on thirty-four cases of stabilizing operations of the spine in which beef bone was added to Albee's technic of fusion, found no evidence of irritation or inflammation around the bone grafts, and examination of the specimens showed evidence of new bone formation in most of the cases. The advantage of beef bone lies in its ready availability and in the fact that it shortens and expedites the operation. Brown observed beef bone splints imbedded in the body as long as four and a half years without noticing any signs of irritation. Aside from the shortening of the operation, there is also the saving of an extra incision to obtain an autogenous graft, and the better opportunity of preparing the bone splint beforehand and fitting it accurately into its bed. Gallie,[71] who since 1914 advocated the use of beef bone, found experimentally that the graft unites solidly to the spine and he obtained with it the same results as in autogenous grafts. Complete replacement of the dead transplant by gradual substitution takes place without premature absorption of the transplant which acts as a scaffold. The disadvantage of the beef bone splint is that it is a foreign body which acts as a scaffold only, having no regeneration of its own, and that subsequently bone substitution does not go on so rapidly as it does through the autogenous bone graft, part of which always remains living. Another objection made to the beef bone technic is that the chances of incurring mild infections are greater (Albee).

Guiterrez[80] used, in place of a tibial graft, the rib from another patient and obtained healing by primary union. The advantage of the rib is its curved shape which adapts itself more suitably to the kyphotic spine.

Technic of Hibbs'[89] Operation (Plate LXIII, 3, 4).—In Hibbs' technic the intervertebral articulations are obliterated and bone bridges are produced which form in the end a solid fusion between the neural arches and the spinous processes. The important point of the technic is the careful stripping of the soft parts from the spinous processes and neural arches laterally until the bases of the transverse processes are reached. The entire dissection must be done in the subperiosteal layer, and this can only be accomplished by most careful stripping. If this layer is not strictly followed there is a good deal of hemorrhage and the operation becomes uncertain as to its ankylosing effect. The intervertebral articulations are scooped out and then bony bridges are recovered from the neural arches and laid across the gaps between the arches. Finally the spinous processes are broken down and interlaced with each other.

This technic also has been modified in minor details. A combination with Delageniere's[589] technic of osteo-periosteal bone graft is recommended by Lewin.[590]

The writer uses reinforcing grafts of beef bone to strengthen the fusion at certain levels of the spine, especially at the sacrolumbar and dorsolumbar junctions.

(3) *The After-Treatment of Fusion Operation of the Spine.*—After either operation the patient is kept in bed on a posterior spine brace or a bivalved plaster bed for a period of about eight weeks. The fusion is then sufficiently complete to permit the patient to sit up in a body cast, and after six months the patient is allowed to be up and about, provided there are no features in the condition of the tuberculous spine which demand further prolongation of recumbency. At this time the cast may be removed and a back brace applied which should be worn for a period of not less than one or probably two years after operation. Following this the patient is free from any supporting apparatus.

(4) *Statistics on Operative Fusion.*—The operative mortality is small. In the writer's series of one hundred and forty-four cases operated upon (Hibbs' method) for tuberculosis of the spine, there was no immediate postoperative death.

The late mortality is computed by Brackett[29] at 12 per cent in one hundred and sixty-three cases. The writer's statistics show a late mortality of 15 per cent which is somewhat better than the mortality in all kinds of cases under conservative treatment.

The next point of interest is the question whether fusion is actually obtained by this operation. Reports are at hand based upon the anatomic examination of the fused spines which throw light upon the ankylosing property of the operation.

From a study of ten autopsy specimens among six hundred cases of Pott's disease operated at Hibbs' clinic between 1912 and 1922, DeForrest Smith[173] found in nine of the specimens that the area operated upon was transformed into a continuous column of bone including spinous processes, laminae and, in most cases, also the lateral articulations. Only in one case was there an irregular break across the bony column which was occupied by fibrous tissue. In view of the fact that the possibility of obtaining fusion of the spine in young children is doubted, the report on the spinal column of a child eighteen months old dying from pneumonia three months after fusion operation is of particular interest. Here, the spinous processes, laminae, and articulations, from the 1st to the 6th dorsal vertebrae, were fused into a column of bone, only two of the adjacent spinous processes failing to fuse.

The rapidity of fusion is also evident from a case dying of tuberculous meningitis, which, at autopsy, five weeks after operation, showed complete fusion (DeForrest Smith). So it appears that fusion of the spine can be accomplished by Hibbs' operation in practically all types of cases, a fact which is substantiated by the writer's own experience (Plate LXV, 1). In a number of cases, reoperated, which were primarily operated by the Albee or Hibbs' method, the completeness of fusion obtained by either method was evident.

f. Critique of the Fusion Operations in the Literature.—

General Statistical Data.—

(1) *American.*—The Committee of the American Orthopedic Association, reporting on the merits of the ankylosing operations of the spine, came to the

conclusion that the operation alone does not prevent an increase of tuberculous destruction, nor an increase of the deformity, and that the latter is not materially influenced, unless the treatment is duly supplemented by mechanical support which is to be maintained almost as long as in nonoperative cases.

The x-ray picture gives no definite information as to the completeness of the ankylosis, but it was found that in 80 per cent of the cases examined solid ankylosis or fusion was present. In this country the operative treatment of tuberculosis of the spine by fusion has been accepted, on the whole, with more or less reservation as a standard method, if not in the majority, at least in a certain considerable minority of selected cases.

It seems necessary to us not only to discuss the operative efficiency of this method from the viewpoint of different surgeons, but also to consider the different single phases of the fusion methods in their anatomic, biologic, and mechanical effects. We have mentioned that in 80 per cent of all cases the fusion obtained by one or the other of these methods was complete, and that with improvement of technic this percentage might still be increased. There is no doubt that this method shortens the time of immobilization and that it furnishes a form of immobilization which is vastly superior to that afforded by the external splinting. Doubt and skepticism center rather about the point whether or not there is a favorable influence of the operation upon the general course of the disease, especially in regard to paraplegia and abscess formation.

Combined statistics embracing Albee's[3] cases as well as those of thirty-three other surgeons, and which amount to five hundred and thirty-nine cases, show that an arrest of the disease was noted in 85 per cent. According to Rugh[163] the advantage of fixation is more rapid consolidation of the destroyed area; and the more perfect internal immobilization causes abscesses to disappear which otherwise would continue to exist. This author reports excellent results in 74 per cent of his cases and considers the method as one of choice. Again, from Ashhurst's clinic, John[97] observed 50 per cent of excellent and good results consisting in arrest of disease and firm ankylosis during a period of observation extending from one to four years, the best results being obtained in operations at early stages.

In the writer's own series fully 80 per cent of spinal fusion gave good results and the total mortality of fused cases, in late observation, that is after several years, was 17 per cent.

It is maintained that fusion operation of the spine is an efficient method of internal splinting and nothing more. Even in this case the value of the operation should not be underestimated if one considers that absolute immobilization is the most important prerequisite for a favorable and peaceful course of the disease.

In running parallel series of fused and nonfused cases, Kidner and Muro,[102] find, on the other hand, that in children, the cases in which fusion was done required practically as long and as careful after-treatment as those without

PLATE LXV

Fig. 1.—Specimen showing completeness of operative fusion. (Hibbs' technic.)

Fig. 2.—X-ray of extensive sacroiliac tuberculosis.

Fig. 3.—Patient with sacroiliac tuberculosis (secondary to higher spinal lesion) and ischiorectal abscess.

Fig. 4.—Tuberculosis of os ischii.

Fig. 5.—After sacroiliac drainage. (Same patient as Fig. 2.)

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PLATE LXV

operation. Nonoperated cases, when cured, had the advantage of a more flexible spine, so that the possible shortening of the convalescence does not justify the risk of operation in children. Bradford[31] also expressed the opinion that surgical treatment of the tuberculous spine in childhood is less suitable than the conservative method, and that it is most successful in adults with slight deformity in the lower dorsal spine.

(2) *British and Continental.*—The attitude of British and Continental surgeons on the question of operative treatment of tuberculosis of the spine is still more conservative, and varies widely from an absolute rejection of the method under any and all circumstances to conditional acceptance. Some of those who reject the operation unconditionally (Calvé,[41] Galeazzi[70]) argue that the late mortality is higher than in nonoperated cases, a point not borne out by the experience of American surgeons. Several observers hold the view that the plaster jacket remains the sovereign method as it produces as good results as the operation (Bade,[13] Lexer[116]). Practically all surgeons exclude children of tender age and all those who are poor operative risks (DeFrancesco). Many believe that the operation does not in itself effect any cure but that this is effected by the general hygienic measures with which the operative treatment is combined (Debrunner[52]).

Estor,[61] a French surgeon, believes ankylosing operations not indicated in children, while he admits the value of this operation in adults, but only as a supplement to immobilization and recumbency methods; others advance the operative risk as an argument against operation in children (Nové-Josserand[134]). Among foreign observers, the opinion of Waldenström[202] is of especial interest, since this surgeon commands more experience in the matter than most of the Continental observers, having operated up to 1922 one hundred and one cases of spondylitis tuberculosa with no operative death. In a series of eighty-eight cases reported, sixty-six were under fifteen, and the rest over fifteen years of age. Of the sixty-six children, fifty-eight healed with excellent functional and cosmetic results, moving like normal people and engaging in all kinds of activities and sports. Of all eighty-eight cases 80 per cent had good results without kyphosis. In Waldenström's plan of treatment, however, a thorough correction in the Lorenz inclination bed precedes the operation, and the spinal fusion is undertaken only after correction is obtained; besides, this surgeon excludes children in the active state of spinal tuberculosis. They are never operated on and remain in the reclination bed until the tuberculous process of the vertebral body has come to a standstill. In contrast to Waldenström others consider beginning cases of spondylitis as especially favorable for operation (Denk[56]); others again see in all symptoms on the part of the spinal cord indications for fusion, which they combine in severer cases with laminectomy (Denk,[56] Vorschutz). Most of the observers object to operative fusion of the spine in all children but concede the indication for adults, especially in cases which refuse to submit to methodical orthopedic treatment (Courboules[48]).

(3) *Theoretic Considerations.*—These few illustrations from an exceedingly voluminous literature will indicate to the reader the discrepancy and confusion of opinions and the difficulty of arriving at individual and independent conclusions. So much greater is the need of going into the theoretic premises necessary for the success of these operations.

(a) The Mechanical Effect of the Graft Upon the Spine. The mechanical effect of internal splinting upon the cessation of pain caused by spinal motion is generally recognized. It is also conceded that the immediate and absolute fixation of the diseased focus made possible by operation exerts a favorable influence upon the course of the disease. Nevertheless, the earliest expectations of rapid cure have not materialized. In progressive cases one notices even after years a decrease in the resistance of the graft resulting in progressive deformation of the latter. So it seems that the graft alone is not sufficient for the definite support of the spine. A rapid cure of spinal caries cannot be forced no matter how strong the implant may be since the caries is only the local expression of a general tuberculous disease, requiring its appointed time for cure.

Deformity. The opinion that the graft acts as a correcting factor upon the gibbus is disputed by many surgeons even though they are otherwise adherents of the operation. Koenig[106] and Vulpius decidedly believe that the graft has no corrective effect upon the gibbus and some adherents of the operation, among them Waldenström, do their correcting of the deformity before the operation is undertaken.

Abscess. Similar opinions exist concerning the effect of the operation upon the abscess. Some few report rapid retrogression of abscesses, but most of the observers deny the direct effect of fusion operation upon abscess formation (Görres,[79] Borchard, Koenig,[106] Fromme).

Spinal Compression. Regarding the effect of the operation upon spinal compression most Continental surgeons hold that in the very beginning of compression symptoms, retrogression was noted, while in more advanced cases there was no change noted from the operation. Therefore, for severe compression symptoms the laminectomy is the operation of choice if any operation is indicated at all (Koenig[106]). On the other hand, the fusion, even if only an adjunct to immobilization, is a most important as well as a most effective one, and one must not commit the mistake of crediting the postoperative treatment or recumbency with all the beneficial effect which follows after operation (Patel[141] and Creyssel).

(b) Mechanical Effect of Spine Upon Graft.—It is only under certain conditions that the graft can fulfil its function as a support for the collapsing spine. At the site of disease there are two types of changes in the relation of vertebra to vertebra: there is the telescoping of the vertebrae into each other, and there is the forward flexion or inclination (Girdlestone[75]). The telescoping involves the sliding of the lateral articulations and the crowding together of the dorsal apophyses. When this telescoping has reached its limit and the destruction still continues, then the second process, namely, the forward flexion of the spine comes into play until the anterior surface of the body above the gap becomes opposed to the upper surface of the vertebra below. This position is called by Menard a complete inflection, and it involves the subluxation of the intervertebral articulations. These simple mechanical conceptions are of fundamental significance for the understanding of the supporting function of the graft. In the extended position of the spine the weight-bearing pressure is taken up by the posterior column which is then taxed for its weight-bearing properties. In the case of a graft or interlaminar bone bridge such strain necessarily falls upon the posterior spinal graft or the bone bridges, provided for by operation. As long as the weight is shifted to the posterior column the fused portions of the spine sustain only pressure stresses and under these they are likely to hold. If, on the other hand, the upper segment goes into forward flexion, then tension stresses develop in the graft or in the fused area, and these tension stresses are more likely to result in atrophy of the graft or the fused portion of the posterior column.

But, when the tuberculous destruction of the vertebral body has come to a conclusion and the contours of the bodies again appear sharply defined, and when there is a definite and complete contact of the bodies against each other, this blocking and interlocking of the vertebral bodies prevents further deformity, and the tension stresses upon the graft are now met by the anterior blocking. For this reason fusion of the graft is rejected by many in the active stages of disease, since the natural blocking of the vertebral bodies is, then, not complete. On the other hand, when activity of the process ceases and repair is fully developed, the graft will not have to militate further against a flexion propensity of the collapsing spine, and a better mechanical effect of the operation can be expected (Dubois[60]). So we see that even among the conditional adherents of the operative method the opinion gains ground that sound healing of the spinal lesion and effective resistance of the body should be waited for, either before the internal splinting is undertaken, or, better, before internal splinting can become independent of recumbency. Under these premises the internal spinal fixation is reliable and has great value as part of the conservative treatment of Pott's disease in adults. In children, however, it is less reliable and at the same time less suited (Girdlestone).

This interrelation of mechanical effect between spine and graft explains, we believe, much of the criticism against the unrestricted use of internal fixation. It gives substance to the argument that the favorable effect of the operation is largely attributable to the quiescence of the tuberculous process, the stationary condition of the gibbus, and the blockage and interlocking of the vertebral bodies (Mau[124]); that operation alone in the progressive stage does not give sufficient support (Roos[161]); and that internal splinting is much more effective in the lumbar than in the dorsal spine.

(c) The Fate of the Graft. The interrelation between spine and graft has also its biologic expression in the histologic changes observed after operation. It has been stated that the graft fulfills its function as a weight-bearing instrument under certain conditions only, i.e., if subjected to pressure stresses, and that tension stresses will lead to absorption and pseudoarthrosis in the graft. To be correct, only a very limited degree of tension stress is tolerated without atrophy (Dubois[60]). These mechanical laws explain the greater hazards for the graft in the kyphotic dorsal spine and the more favorable conditions in the lordotic cervical and lumbar sections. These laws apply, in general, to children as well as to adults. In the latter, however, the lesser elasticity of the intervertebral discs and the greater resistance and lesser pliability of the vertebral bodies, cause the posterior column, viz., the pedicles and arches, to assume more of a weight-bearing function than they do in children, and, consequently, the outlook for permanency of the graft is here much more favorable. In adults, also, we have the frequent epiphyseal type in which anteroposterior deformity is less pronounced and there is much less tendency to forward collapse.

All these considerations are essential and they help to clear up many apparent discrepancies between the advocates of early and those of late fusion. It also explains why the fusion operation as a means of internal fixation must be, in most cases, combined with recumbent treatment.

(d) Signs of Arrest of Deformity.—Complete stop of the deforming tendency is indicated by the bony block between the affected and deformed vertebral bodies. The perfect coaptation is also expressed in the architecture of these structures. In a case of healed deformity one sees the lines of pressure stresses run obliquely from above and backward to downward and forward in the upper vertebrae and in opposite direction in the lower. So the gibbus is shaping itself for its ultimate static and dynamic structure; it is, as Dubois expresses it, more a reaction of growth than simply the mechanical result of the forward collapse of the spine. We see, then, that the behavior of the graft to pressure and tension stresses, as discussed before, is good reason why one should consider the standstill of the deformity necessary for the function of the graft, and a progress of deformity inimical to it.

(e) Effect of Graft on Growth of Spine.—The experiments of Nussbaum[136] showed that the graft produces a lordosis and retards the growth of the entire spine. Pusch[148] investigating specimens of spinal graft nine years after operation, found that the transplant does not grow in length but increases in width. This is corroborated by Fromme,[66] who also denied the length growth of implants, contrary to Albee's and Hoessly's views, who considered length growth of the implant possible. The implanted graft investigated by Pusch[148] had lost 2½ cm. of its original length by absorption but there was considerable increase in width.

(4) *Résumé.*—The fusion operation provides absolute immobilization of the spine by transforming the posterior column into a solid and unyielding sheet of bone. This fact has been amply demonstrated by postoperative biopsies and by autopsies; such fusion can be accomplished in children as well as in adults. The immediate mechanical effect of the fusion as an

absolute means of fixation of the spine is the only feature of which we are reasonably certain. All beneficial effect of the fusion rests upon the soundness and completeness of this internal splinting. On the other hand, the importance of such complete immobilization for the course of the disease is not to be underestimated. Though it does not prevent or influence the formation of abscesses or the occurrence of spinal compression, this absolute internal fixation makes the collapse of the spine and the reinfection of opposing bone surfaces of the bodies much less likely. Accordingly in a great number of cases the final course of the disease is favorably influenced by the direct effect of complete immobilization. In children, undoubtedly the indication must be drawn much more restrictedly than in adults, but in the latter, especially if the seat of the disease is the lower dorsal or the lumbar spine, the fusion operation is of distinct benefit.

There can be no objection to operation in early cases so long as it is realized that they depend on recumbency, regardless of operation, until the adequate stage of repair is reached. In later cases it is obvious that either the destruction leading to deformity must have come to a halt, so that the graft functions merely as a weight-bearing support and not as a brace against forward bending, or else operation must also be combined with recumbent treatment until, again, this point is reached. In other words, in those regions of the spine in which the forward bending stress prevails, i.e., in the dorsal region, a graft or a fusion will not prevail against it without a sufficient degree of natural repair. This proves the correctness of observers like Waldenström and others, who make it a point to carry out the redressment of the deformity before the operation.

In certain inveterate cases with abnormal mobility within the region of the gibbus the operative measures are indicated to obliterate this motion. To these also belong cases with involvement of several vertebrae and with lack of functional repair, incomplete callus formation, instability of the spine, and often with neuralgic symptoms; also the cases with impingement symptoms or secondary strain, principally in the lumbar or lumbosacral regions; in all these fusion operation is indicated.

g. **Cosmetic Operations for the Projecting Gibbus. The Subperiosteal Resection of the Spinous Processes.**—Many years ago Calot proposed this method in order to facilitate the forcible redressment of the spine. The resection of the spinous processes protruding at the site of the gibbus is justified as a cosmetic procedure, and to make the application of supporting apparatus easier. A number of these operations were performed in Codivilla's clinic (Sangiorgi[166, 167]) in cases in which the spinous processes were very prominent and interfered with corrective apparatus, or other corrective measures. The technic of this simple procedure is as follows: a curved incision is made around the gibbus involving skin and subcutaneous tissue; then the flap is turned to the side, the spinous processes are next exposed. Dissecting through the fascia they are stripped and removed by bone cutting forceps.

IX. SACROILIAC TUBERCULOSIS

Primary localization of tuberculosis in the different bones of the pelvis is not frequent. Valtancoli[194] finds forty-nine cases of tuberculosis of the pelvis against 1271 of tuberculosis of the spine in his collection from the Institute Rizzoli. Of these forty-nine cases thirty-one were tuberculosis of the sacroiliac region, seven of the sacrum, five of the os pubis and symphysis and six cases of the os ilei itself.

1. Pathology

Sacroiliac tuberculosis is so rarely found in infancy that its existence at this period is doubted (Menard). It is most frequent in the second and third decades (Gangolphe). From the twenty-fifth year on it again becomes less frequent. In all cases reported by Valtancoli the affection was unilateral. Most cases belong to the granulation type, and 71 per cent were complicated by abscess formation. In the initial stages the x-ray picture may be entirely negative. As the destruction proceeds, however, the outlines of the joints become blurred, and in advanced stages erosion and destruction along the lines of the articulations may be seen (Plate LXV, 2). Old healed cases show fusion and disappearance of the joint lines.

2. Etiology and Pathogenesis

Hereditary and predisposing diseases play the same rôle as in tuberculosis of the spine. In 29 per cent of the cases familial tuberculosis was found (Valtancoli).

Trauma seems to play a very subordinate rôle, it being mentioned only in a small percentage of the cases (16 per cent, Valtancoli).

Roederer[157] and Van Hook, however, regard trauma as a factor in sacroiliac disease, and according to their opinion, its incidence seems to be somewhat higher than in tuberculosis of the spine although not so high as in tuberculosis of the hip. By far the majority of cases, however, have a gradual and spontaneous origin.

3. Symptomatology

The most prominent symptom is pain, which at first is intermittent. In the earlier stages the patient complains occasionally of radiation in the distribution of the sciatic nerve. In more advanced cases the pain becomes more continued and it is accompanied by limp. In tuberculosis of the sacrum Barré and Schrapf[16] describe caudal symptoms, severe paroxysmal pain, superficial anesthesia with intact deep sensation, degenerative muscular atrophy, constant fibrillary contractions, abolition of the tendon reflexes, and urinary and rectal retention. Spontaneous pain is felt in the joint and extends from here downward to the thigh or groin, or is often referred to a definite area in the lower leg or the foot.

The local examination shows very distinct tenderness over the synchondrosis to direct pressure as well as upon lateral compression of the pelvis. The movements of the hip are free and there are no signs of involvement of this joint. A swelling appears over the articulation. Considerable infiltration of the tissues can be made out, later fluctuation and abscess formation develop. There is seen marked atrophy of the buttocks after the tuberculous affection of the joint has existed for some time (Plate LXV, 3).

In standing or walking the body is inclined away from the affected side. In rising the spine is usually held rigid, the hands are frequently used for support, and in stooping flexion of the trunk is carefully avoided. Any movement of the body or the hips which would entail a strain upon the sacroiliac joint is carefully refrained from. Forward flexion of the trunk is always accompanied by early flexion of the knee.

Abscess Formation.—In 29 per cent of Valtancoli's cases abscesses were found; of these 66 per cent were extrapelvic and 23 per cent intrapelvic abscesses. Other statistics, however, show a prevalence of intrapelvic abscesses. Bardenheuer, for instance, estimates the percentage of the intrapelvic abscesses at 80 per cent; and according to Young the intrapelvic abscesses exceed in number the extrapelvic ones, at the ratio of 2 to 1.

4. The Prognosis

In sacroiliac tuberculosis the outlook is better in children than in adults. It becomes more grave in cases of abscess formation and especially so if sinuses develop and the abscess assumes a septic character. In all cases of Valtancoli's series the mortality was only 11 per cent.

5. The Treatment

a. Conservative.—The treatment consists in immobilization of the articulation by plaster of Paris cast. The cast must reach from under the axilla to the knee upon the affected side. The treatment with plaster casts must be extended over a period of two years at least at which time the cast may be replaced by a movable brace. Weight-bearing is especially detrimental and the use of crutches must be continued long into the ambulatory period.

b. Abscess.—The abscesses are treated by the usual method of aspiration by trocar, are emptied and then closed. In cases of abscess formation with mixed infection drainage becomes necessary. The transsacral drainage can be carried out either by Picqué's[146] technic or by Bardenheuer's partial resection of the pelvis, if wider communication appears necessary. The Picqué operation or the drainage operation of Smith-Petersen[179, 180] becomes inadequate in septic intrapelvic abscesses and it then becomes necessary to remove a substantial portion of the sacrum and of the adjacent portion of the os ilei to provide for sufficient drainage. Following the operation the patient is placed in a double hip spica reaching from the axilla to the knees. This operation was carried out by the writer in five cases for suppurating chronic abscesses originating from sacroiliac tuberculosis; in three, drainage became sufficient and the patients improved (Plate LXV, 5).

c. Operative Fusion.—In caries sicca of the sacroiliac articulation where no drainage is necessary, the operative fusion of the articulation can be carried out. The best method is the one of Smith-Petersen.[179] (Plate LI, 1, 2.) Its technic is as follows: a curved incision is made running from the posterior superior spine along the crest, two-thirds forward toward the anterior superior spine, and is then continued from the posterior angle downward to the posterior inferior spine. After division of skin and superficial fascia, the incision is deepened to the periosteum which is stripped off with the covering muscles until the posterior portion of the outer flare of the os ilei lies bare. Superior gluteal nerve and artery are avoided by keeping away from the horizontal border of the greater sciatic notch. A rectangular opening is then made into the bone with the longer side paralleling the lower edge of the os ilei, measuring one and a half by one inches. This cut reaches the sacroiliac articulation. The bone peg, so obtained, is lifted out and the articulation underneath is then destroyed by curetting away the fibrocartilaginous layer from the os ilei as well as the opposing joint surface of the sacrum. It is then replaced and countersunk by bone chips or pegs. The wound is closed.

Smith-Petersen reports seven cases of tuberculosis of the sacroiliac joint which had been arthrodesed in this manner and were observed for three years with gratifying results.

Albee's[4] method of immobilization of this articulation consists in the application of an inlay graft laid into the sacroiliac articulation. There are several modifications: either a bone bridge graft is carried from the sacrum to the wing of the os ilei or an inlay bone graft into the sacroiliac joint itself is made, or, finally, a bone graft, inlaid into the wing of the os ilei, is morticed to a second previously prepared spinal bone graft. This method is useful especially for the combined tuberculosis of the fifth lumbar and that of the sacroiliac joint.

Technic of Albee's[4] Method (quoted). (Plate LXIV, E, F.) The posterior superior spine, the wing of the os ilei, the first spinous process of the sacrum, are all reached by a transverse incision. The spinous processes of the last one or two lumbar vertebrae are split with their attached ligaments by a thin wide osteotome forming a groove to receive the end of the graft. Then a cut is made in the posterior wing of the os ilei by driving a thin osteotome one-half inch wide into it, just anterior and medial to its posterior superior spine, in a direction laterally from within outward. The lateral graft which is secured later, is forced into this cleft while its other end is joined to the spinal graft laid into the spinous processes of the last two lumbar and the first two sacral vertebrae. All the grafts are recovered from the crest of the tibia by motor-saw, and their width should be about three times the thickness of the cortex. After being placed the grafts are secured by interrupted sutures of kangaroo tendon.

X. TUBERCULOSIS OF THE PELVIS

1. Tuberculosis of the Os Ilei

a. Pathology.—The following types are distinguished (Menard[127]):

(1) Tuberculosis of the os ilei and of the upper margin of the acetabular cavity. This type is a feature of acetabular disease. Sequestration in this form is rare.

(2) The second type of pelvic tuberculosis is localized at the crest of the os ilei, usually at the upper portion, forming a cavity over the outer layer of the os ilei close to the anterior portion of the crest.

(3) In a third type tuberculosis involves the posterior portion of the os ilei, where a swelling becomes established and an abscess forms. This is often mistaken for tuberculosis of the sacrum or the lumbar spine.

(4) In a fourth type the tuberculosis involves the internal table of the os ilei producing an intrapelvic abscess.

b. Symptoms.—As a whole, tuberculosis of the os ilei does not present a very characteristic clinical picture. The disease begins with intermittent pain which is referred usually to the hip joint and is accompanied by a limp. The hip is held in slight flexion and abduction, but hip motion is otherwise not particularly restricted. A painful area is found over the os ilei, particularly over the crest. By manual compression of the os ilei the pain can be elicited. Abscesses are present in 60 per cent of the cases, and they are usually extrapelvic (Valtancoli).

c. The Treatment.—The treatment of tuberculosis of the os ilei is operative, and consists in the removal of the diseased portion of the bone and ample drainage. Cases requiring total resection of the os ilei are rare. Nelaton[132] reports a case in which the resection of the os ilei was performed, the bone being removed from the sacroiliac junction after the horizontal ramus of the os pubis had been cut through. In this case a favorable end-result was obtained.

2. Tuberculosis of the Os Pubis and Os Ischii

Both localizations are rare. The first case of this kind was observed by Ollier[140] in 1867. Jackson[95] reports one case, a girl of eleven years old, with destructive lesion of the pubic bone and abscess formation, the pus giving a positive guinea pig test. There was no evidence of bone proliferation.

a. Pathology.—The process starts as a tuberculous perichondritis or periostitis, sometimes as a tuberculous osteomyelitis of the cancellous bone (Plate LXV, 4). Pus formation and sequestration occur. Abscesses and sinuses develop, the latter opening usually above the symphysis. Gravitation abscesses are likewise observed, most frequently opening at the perineum, the scrotum, or the ischiorectal fossa. In children the lesion is exclusively osseous, the cartilage layer protecting the intrapubic articulation from invasion. The sequestrum almost constantly occupies a considerable portion of the body. Only in one case the symphysis was found involved in a child (Valtancoli[194]).

b. Clinical Symptoms.—The clinical symptoms are not very characteristic. The most constant one is pain and it is usually strictly localized at the seat of the disease. It is often accompanied by claudication due to the rigidity of the hip joint. Abscess is most commonly found in the groin, and on the inner side of the thigh, corresponding to the adductors; only occasionally the abscess extends toward the trochanter region. According to Herz[88] a location of the abscess in the hypogastric region is found prevailingly in those cases in which the primary disease is at the symphysis, while in the cases in which the disease is in the descending branch of the os pubis or in the os ischii, the abscesses are found to appear in the adductor region. Menard[127] found abscesses in the adductor region eleven times and four times in the hypogastric region. According to him the tuberculosis of the pubic bone develops after a long period of latency, since there is no particular trouble as long as the focus is inclosed in the bone. Occasionally the patient will complain of pain in the early localized stage of the disease and attention will be called to the condition. Such early diagnosis is of inestimable value because it makes the treatment much more simple and shortens the duration of the disease. The first clinical manifestation, however, is, as a rule, a tuberculous abscess which occupies the above named two principal locations, namely, the groin and the hypogastric region. Such an abscess is usually not very painful, develops slowly, and remains stationary for a long period of time. The hip joint responds with slight adduction due to the infiltration of the adductor region and abduction may be limited. So may also the flexion of the hip, but there is never seen a concentrical restriction of motion such as exists in hip disease. Involvement of the bladder is not very frequent and is by no means always associated with hypogastric abscess. A case is cited by Menard and Duplay in which a vesical fistula existed which did not become continent until a sequestrum at the posterior surface of the os pubis was removed at operation.

c. The Treatment.—Almost always the surgeon has to confine himself to an incision of the abscess if the latter does not break spontaneously. When a fistula has become established, it should be sounded and the tract determined. The operation for the removal of the sequestrum is simple; the tract of the fistula is incised and followed up to the bone. The abscess cavity is located in the bone and, if necessary, enlarged until a wide communication is established.

XI. COMMENT ON CHAPTER VI: TUBERCULOSIS OF THE SPINE

Tuberculosis of the spine must be considered as representing a tertiary manifestation of systemic tuberculosis. Therefore, the whole management and plan of treatment serves primarily the interests of the patient's constitution from which must ultimately come the resources that control the infection.

Tuberculosis of the spine, on the whole, does not take a malignant course. The majority of cases are inclined to follow a definite biologic cycle from invasion to repair. It is, consequently, amenable and responsive to persistent and timely curative measures.

In the nature of this condition this biologic conclusion occurs in children earlier and more definitely by the formation of a bony block, whereas in adults the ultimate result of the pathologic process is scar tissue, which is less reliable so far as the arrest of the deformity and the termination of the disease itself are concerned. For this reason cures accomplished in childhood are more permanent in general than those of middle and later ages. The deformity is no indication of the persistence or even the severity of the disease.

Of all external forces of local nature by which the course of the disease is unfavorably influenced, weight-bearing is the worst. Unlike mobility of the spine it cannot be eliminated by muscle contracture, but is a constant and efficient force making for deformity and bone destruction. Therefore, measures which eliminate weight-bearing are, in the initial stages as well as beyond these, by far the most efficient means to control the further course of the disease. Of these measures, recumbency is the only reliable one and must be given the fullest consideration, regardless of time, until its ends are fully achieved.

Under the recumbency treatment one can expect full control over the development of deformities of the lumbar and lower dorsal sections, and to a lesser degree, control over the upper dorsal and cervical spine.

Abscesses in the majority of cases will disappear, thereby avoiding incisions and punctures. The indication for heliotherapy and other hygienic measures will become obvious from the foregoing remarks; they are adjuvants of recumbency treatment.

Ambulatory treatment supplants recumbency in stages when systemic repair in the tuberculous region is already advanced to such a degree that collapse of the spine is no longer to be feared. All of the general conditions demanding bed-rest must have disappeared before ambulatory treatment is to be instituted. The general condition and, largely, the x-ray picture decide this question. The x-ray also determines the point at which external fixation during ambulatory treatment can be relinquished; here also, one must be cautious and take recourse to other corroborating evidence of accomplished healing from general and local signs, since apparent consolidation in the x-ray of the involved bone does not always mean complete healing.

As far as the palliative methods of internal splinting and spinal fusion are concerned, the situation may be summed up as follows: they may be undertaken early or late, provided they do not encroach upon the time limit for recumbency; that is to say, spinal fusion in early stages will be beneficial only if combined with recumbency treatment to almost the same extent and duration as in nonoperative cases.

In the ambulatory cases, however, the advantage of internal fixation of the spine becomes more apparent, because the immobilization provided thereby is vastly superior to that offered by external appliances; so, that, if any curtailing of the duration of the disease is accomplished by palliative operative methods of fusion, or internal splinting, it is the ambulatory stage and not that of recumbency which is shortened.

As much as conservative methods are advisable in pure tuberculous abscesses as much is radicalism frequently necessary in dealing with septic infections. The surgery of drainage of large, deep, tuberculous abscesses, which have become septic, is by no means a settled point. Some of the most important operations have been dealt with in this chapter, but statistics on the end-effect of these drainage operations are still meager. In view of the severity of the condition and the very unfavorable outlook in general, more study and more data on this point are urgently needed.

Paraplegia is the next important complication in tuberculous spondylitis. It yields to recumbency and extension in the vast majority of cases in children; in the adult and more advanced age, however, there are more and more exceptions. The attitude should be taken, to be conservative and patient in the management of compression paraplegias, and to allow for sufficient time for the effect of conservative treatment to become manifest. It is equally necessary, however, to recognize promptly the many exceptions which will resist conservative treatment, and which demand operative measures, so that the operation may be performed sufficiently early, that is, before signs of sensory disturbance and flaccidity appear.

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CHAPTER VII

OSTEOMYELITIS OF THE SPINE

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    - 2. Localization
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H. Typhoid Rib
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    2. Symptoms
    3. Treatment

I. Comment on Chapter VII: Osteomyelitis of the Spine

CLASSIFICATION AND DEFINITION

According to Mathieu,[32] Lannelongue[28, 29] was the first to give a description of acute osteomyelitis of the spine. It is an infection so uncommon that Grissel (1903) found but eighty-five cases reported in the literature.

Following Mathieu one may distinguish the following types: (1) the acute form, adolescent type, due to the ordinary pyogenic organism, the most frequent of which is the Staphylococcus aureus: (2) the pyogenic, staphylococcus type, subacute or chronic form, much rarer than the former; (3) the chronic granulation (strumous) type following typhoid, paratyphoid, etc.

A. ACUTE PYOGENIC OSTEOMYELITIS OF THE SPINE

I. Statistics

1. Incidence.—Vertebral osteomyelitis is observed in the growing age, from twelve to fifteen years, the age in which the secondary centers of ossification of the spine make their appearance. Cases occurring after the thirty-fifth year are the exception. The greatest frequency usually falls into the second decade. According to Donati[6] the incidence is 68 per cent in males and 32 per cent in females. It seems also, that while the cervical osteomyelitis is divided equally between the sexes, the female sex is favored by localization in the dorsal spine with almost the double frequency of the male, while the localization in the lumbar spine is more often observed in the male.

2. Localization.—According to localization one may distinguish the following groups: (1) cases involving the posterior arches, and (2) cases involving the vertebral body.

Involvement of the arches is much more frequent than that of the body. It is also much less severe and less dangerous than the latter localization.

In regard to the tissues involved, three forms may be distinguished: (1) a phlegmonous type which forms periosteal abscesses; (2) an external periostitis with abscesses located between periosteum and musculature; and (3) an endosteal osteomyelitis to which all severe cases of osteomyelitis of the epiphyses, apophyses, the laminae, and of the vertebral bodies, belong.

II. Etiology

1. Infectious Agent.—Staphylococcus pyogenes aureus is the usual cause of the osteomyelitis of the spine. In a smaller percentage we find the staphylococcus albus and exceptionally the streptococcus (Mayer[33]).

2. Trauma.—Trauma seems to have an etiologic significance in so far as it produces a point of lesser resistance and thereby favors the colonization of microorganisms. A blow or a fall against the spine may predispose to subsequent vertebral osteomyelitis. Osteomyelitis of the spine may also follow upon fracture or contusion without external wound, or finally a latent osteomyelitis may become manifest by trauma. To establish the connection between trauma and osteomyelitis it is first necessary to prove the occurrence of the injury and the fact that the patient immediately before the injury showed no signs of fever, pain, swelling, etc., and, secondly, to show that the interval between the accident and the first symptoms of osteomyelitis is marked by local pain, and impairment of function as well as by general symptoms. It does not seem logical to admit the connection between contusion or injury without open wound, and a following osteomyelitis when an interval of more than eight days has passed during which the patient was free from pain and other symptoms. Nevertheless, cases of undoubted traumatic etiology of vertebral osteomyelitis have been described (Dudden[7]).

3. Port of Entry.—In most cases osteomyelitis of the spine is metastatic. The original focus, as in osteomyelitis in general, is mostly a furuncle, a felon, tonsillitis, upper respiratory infection, or occasionally a contagious disease.

III. Pathology

1. Pathologic Classification.—While tuberculous osteomyelitis almost always selects the bodies and very rarely the arches of the vertebrae, purulent or pyogenic osteomyelitis has a great preference for the arches and the processes of the vertebrae, and much more rarely involves the vertebral bodies themselves. According to Donati[6] the osteomyelitis occurs in the arches in 56 per cent, and in the bodies in 25 per cent, while diffuse osteomyelitis of the vertebrae is observed in 9 per cent only. To this must be added the occasional involvement of the intervertebral discs. A case of this kind is reported by Mayer.[33] It was a girl five years of age, in whom the x-ray picture showed no destruction of the vertebral bodies but a narrowing of the intervertebral discs leading to kyphosis. Such changes are well known in typhoid spines where the ultimate result is disappearance of the intervertebral disc with subsequent synostosis, but, primary involvement of the intervertebral disc is the great exception in pyogenic osteomyelitis.

2. Osteomyelitis of the Vertebral Body.—The osteomyelitis of the vertebral body, so well described by Lannelongue,[28, 29] presents itself either as a subperiosteal form, as an epiphyseal separation, as a rarifying ostitis, or as the destructive ulcerative type. It occurs most frequently in the second decade and most often involves the lumbar, less frequently the dorsal spine. Again, more often a single vertebra is involved, and only occasionally the disease extends over two, three, or more vertebrae. Sometimes only the surface of the vertebra is attacked in form of osteoperiostitis, at other times there is a rapid invasion of the spongious substance and the entire body of the vertebra may become infiltrated with pus and succumb to necrosis; in this case we find that the intervertebral disc secondarily becomes separated from the bodies of the vertebrae and disappears. The extension of the disease along the spinal canal through the vertebral body is as frequent as it is in osteomyelitis of the arches. Then purulent pyomeningitis develops and pus is often found in the spinal canal, even though the dura may be intact and the spinal cord shows only hyperemia. In other cases, again, the cord itself becomes the seat of a metastatic foci carried to it by the collateral blood stream. Telescoping of the vertebral bodies, as seen in tuberculosis, is almost never observed in acute osteomyelitis for the reason that cases so extensively involved as to lead to massive destruction of the bodies usually come to a fatal end much sooner. Osteomyelitic abscesses on the other hand, usually make their appearance sooner or later as deep-seated abscess formations. The primary location of the abscesses is the anterior portion of the vertebrae; from here they slowly gravitate downward following similar routes as are used by the cold abscesses in tuberculous spondylitis, only that pus formation in osteomyelitis is much more rapid than in tuberculosis.

There are three principal routes of migration: (1) an anterior route with formation of an abscess under the periosteum entering into the mediastinum; (2) a posterior route toward the dura, causing pachymeningitis anterior, and medullary compression; and (3) a lateral route between the bodies and transverse processes. In the lumbar spine the abscess often gains the psoas sheath, in the dorsal spine the peripleural spaces or the posterior mediastinum is invaded; and in the lower dorsal and lumbar spine, the retroperitoneal space often becomes the seat of the penetrating abscess.

A not infrequent complication in osteomyelitis of vertebral bodies is the involvement of other joints, endocarditis, pneumonia, pleurisy.

3. Osteomyelitis of the Arches and Processes (Plate LXVI, 3).—Arches and processes are involved in 58 per cent against 7 per cent of bodies and arches and 44 per cent of the bodies alone. Of the different sections of the spine, the lumbar spine is, according to Volkmann[51] the most frequently involved, namely, 47 per cent.

Osteomyelitis of the neural arches and processes is most frequent in the second and third decade. It occurs in the following types: the type involving the spinous processes is most frequently found in the lumbar region; infection is followed by abscess formation during which the bones become denuded and sequestration takes place.

Another type is the diffuse osteomyelitis of the neural arches. In this group the whole posterior arch is involved including the spinous and transverse processes. In the majority of cases this disease is limited to one vertebra only. On the other hand, extension abscesses enter into the spinal canal causing pachymeningitis and involvement of the peridural tissues. Less frequent are complications on the part of the pleura and lungs, or secondary pyogenic metastases involving other bones or the serous cavities.

A third type is the osteomyelitis of the transverse processes. This group is characterized by formation of abscesses which occasionally attain considerable size. They usually break through posteriorly and migrate along the long muscles of the back, and may descend from their lumbar localization into the gluteal region or in front into the sheath of the psoas and reach the iliac fossa. Occasionally, also, there is penetration of pus from the transverse processes into the spinal canal followed by purulent pachymeningitis.

Combination of osteomyelitis of the spinous processes with that of the neural arches proper is often observed. If both sides of the neural arches are involved, the process extends more frequently over two or more vertebrae. There is special danger of penetration of pus into the spinal canal. More rarely osteomyelitis is limited to pedicles and transverse processes, usually unilaterally. The affected part succumbs to necrosis and is extruded as sequestrum.

4. The Deformity.—Deformity occurs in form of anteroposterior gibbus formation due to collapse of the involved vertebral bodies, but the tendency to the deformity is not nearly as great as it is in tuberculosis in spite of the more rapid destruction of the vertebra. Telescoping, however, without forward inclination is not uncommon. The principal reason for this infrequency of gibbus formation is the acuteness and severity of the condition which prostrates the patient and keeps him on his back, and also the fact that many of the acute cases with involvement of the vertebral bodies succumb at a much earlier stage.

5. Pathology of the Spinal Cord and Meninges.—Any type of vertebral osteomyelitis may be accompanied by meningeal reaction, either in form of

PLATE LXVI

Fig. 1.—Subacute osteomyelitis of body of 3rd lumbar vertebra marked list. (X-ray in Fig. 2.)

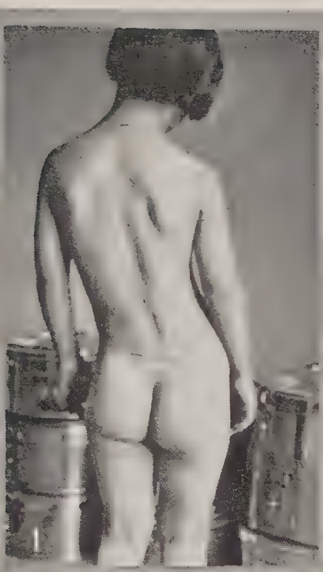
Fig. 2.—X-ray of case in Fig. 1.

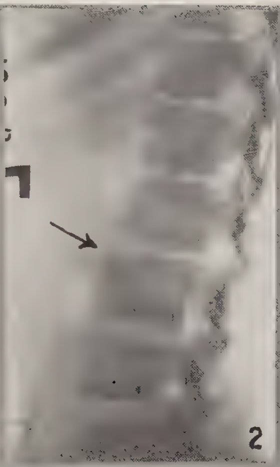
Fig. 3.—Acute osteomyelitis of 2nd and 3rd lumbar. Body and pedicles involved. Extensive bone production. Sclerosis of bodies.

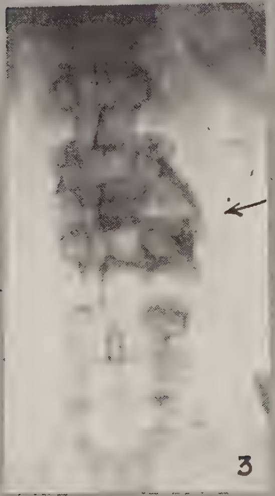
Fig. 4.—Acute osteomyelitis of sacroiliac joint. Rarefaction and destruction. (See Fig. 5.)

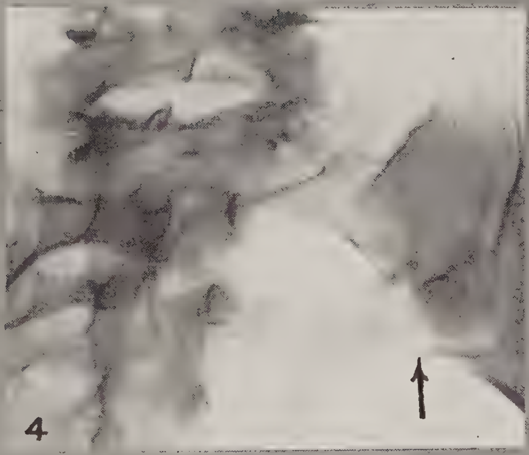
Fig. 5.—Case of Fig. 4. (After operative drainage.)

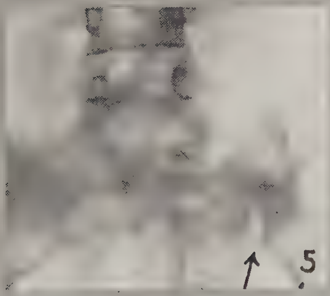
Fig. 6.—Osteomyelitis of sternoclavicular joint, sternum and first rib.











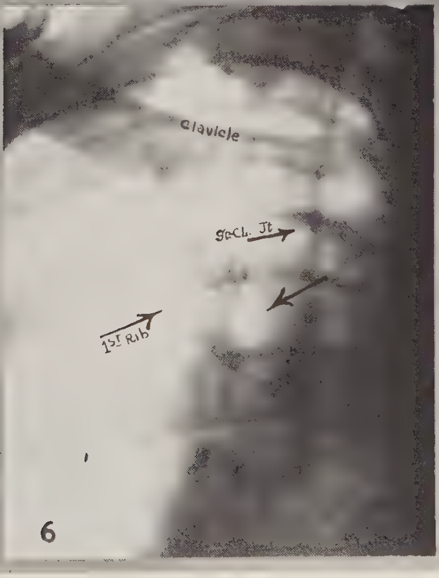


PLATE LXVI

a simple congestion, or more often, as true meningitis resulting from direct continuation of the pyogenic process.

In the cord, we find in a majority of cases hyperemia, edema, or infiltration. In the surviving cases, the change usually does not go beyond this stage. At autopsy often destructive changes of the cord are seen, the patient usually showing, toward the end, flaccid paralysis, sphincter trouble, and ascending urinary infection.

6. Pathology of the Respiratory System.—The respiratory system is often involved either by direct continuity from the dorsal vertebrae, or by hematogenous abscesses.

Abscess formation is the most frequent feature of pulmonary involvement, the latter being either intrapulmonic, or central, and sometimes it becomes extraneous by perforation into a bronchial tree. More often a subpleural metastasis develops producing a purulent pleurisy.

IV. Clinical Pathology

1. Clinical Types.—Four clinical types are distinguished (Mathieu).

a. The osteomyelitis of the growing age is an osteoperiostitis characterized by fever, pain, etc.

b. The subacute form presenting great similarity with Pott's disease and osteomyelitis of a prolonged course.

c. The hyperacute form with abscess formation, involving the vertebral bodies. This latter form is characterized by extreme prostration, violent pain, rapid complications of the lungs or of the medulla.

d. The ordinary acute type, the pathology of which has just been described.

2. Symptoms.—Acute osteomyelitis of the spine is most often seen in young adults and in children between the ages of ten and fifteen, and is accompanied by violent pain in the spine, the lumbar spine being more often afflicted. There is pronounced muscular rigidity, contracture, and tenderness of the back. The temperature and pulse rise rapidly, the patient is prostrated, similar to the condition in typhoid fever, and he complains of radiating pain in the thorax and abdomen, which cause him to avoid even the slightest motion in bed. At this stage the diagnosis is still uncertain because the clinical picture resembles typhoid fever, pneumonia, pleurisy, peritonitis, etc.

Secondary Symptoms. Toward the eighth or tenth day the infiltration of the involved region becomes apparent to palpation, the temperature in the meantime, having remained at 100 to 103. Shortly a diffuse swelling is observed in the back along the long muscles, and one may also detect deep fluctuation. Upon incision pure pus or chocolate colored pus is found in the deeper structures. At this stage one may also find several denuded vertebrae and an extension of the abscess along the transverse processes and the laminae. The further course depends upon the severity of the disease, its early recognition and upon the complications. The cases which go on to cure, according to Grissel about 54 per cent, show rapid improvement, while in the remaining 46 per cent complications arise which lead more or less rapidly to the fatal issue.

3. Complications.—The clinical complications are pneumonia, pneumonic infarcts, abscess of the lungs, subdural abscesses and purulent pleurisy. On the part of the nervous system there are meningeal irritations, true meningitis, medullary compression with spastic or flaccid paralysis, hemiplegia, and symptoms of involvement of the cauda equina.

4. Special Symptoms.—

a. Arches and Processes. Infection of the neural arches and spinous processes usually begins with high fever, dull headache, pain and diffuse swelling. The condition simulates strongly typhoid fever. The patient complains first of severe and localized tenderness at a definite level of the back, and pain is also elicited upon pressure of the involved portion of the spine. All motion is restricted. Edematous swelling appears at the fourth to the tenth day and is often very diffuse and tense. Abscesses develop and usually find their way posteriorly. They rarely form before the end of the second or third week. Donati[6] points out that in osteomyelitis of the arches the pain in the spine is vague in the beginning and is only later referred to the involved vertebra.

b. There is nothing characteristic in the course of osteomyelitis of the pedicles. Infiltration into the spinal canal with perimeningitis as well as involvement of the pleura is frequent. Complications may occur in spite of early opening of the abscess, from metastatic foci, for instance, or from meningitis.

c. Osteomyelitis of the transverse processes is likewise usually acute at the outset. If the abscess is located on one side, a scoliosis of the spine develops with the convexity to the opposite side.

d. Osteomyelitis of the Vertebral Bodies. This type has an especially acute onset and the symptoms are so violent and severe as to resemble typhoid or meningitis. Pain, very acute and intense, is diffuse in the beginning, and later becomes more localized at a certain level. Abdominal and sacral pain often accompanies osteomyelitis of the vertebral bodies of the lumbar spine. Abscesses are difficult to recognize, as they are located in the anterior portion of the spine. They often perforate into the pleura; often the patient succumbs to pyemia before the abscess has had time to reach the surface. Nephritic abscesses coming from paravertebral accumulations of pus have been described. The dorsal deflux of the abscess into the spinal canal with meningeal and cord symptoms, is a common occurrence. Psoas abscesses following osteomyelitis of the vertebral bodies of the lumbar spine produce the characteristic flexion position of the hip joint with intense pain, with symptoms of irritation of the peritoneum, diarrhea, constipation, and meteorism, and occasionally with peritonitis.

V. Differential Diagnosis

In general, the early signs of purulent osteomyelitis of the vertebral bodies are not very characteristic and errors in diagnosis are frequent (Donati). Because of the early pyemic condition, it is impossible to obtain a good examination of the partly comatose patient. Symptoms may resemble rheumatic fever or typhoid, peritonitis, appendicitis, pleurisy, pneumonia, Landry's palsy, or spinal meningitis. The diagnosis rests primarily upon the local signs, namely, pressure pain, referred pain, induration, swelling and fluctuation. The most important symptom is pressure pain at the site of the disease and of the surrounding region. It appears usually before acute inflammatory symptoms are visible, such as swelling and edema. Fluctuation appears later. If the upper cervical vertebrae are involved palpation will reveal tenderness, infiltration, or fluctuation.

Next in importance is the position or posture of the patient assumed for the purpose of immobilizing the affected portion of the spine.

Conditions most apt to cause errors and difficulties in differential diagnosis are the following:

Arthritis of the Spine.—Here, the involvement is more diffuse; there is a difference in the character of the pain and swelling, the mild general symptoms, and the gradual onset.

Of other nonsuppurative affections there are to be mentioned the typhoid spondylitis which has its seat in the lower portions of the spine and is characterized by spontaneous pain, yielding to immobilization. There is no inclination to suppuration. The same is true of other nonsuppurative diseases of the spine, of luetic affections, or of metabolic types of arthritis. (See Chapter IX, Spondylarthritis.)

The condition which most often simulates osteomyelitis is Pott's disease. The latter usually has a slow and insidious course, but not infrequently produces more acute exacerbation. At times, only the most careful history, considering especially onset and course, together with a painstaking analysis of all clinical signs will enable one to make the diagnosis. Often histologic examination of inflammatory tissue, or inoculation of the abscess material is necessary to determine the character of the affection.

VI. Prognosis

On the whole, the prognosis of ostemyelitis of the spine is grave. According to Mathieu the mortality is 46 per cent, death being due to complications: involvement of the pleura, or penetration of the pus into the spinal canal, or general pyemic infections. Abscesses with pleural or pulmonary complication play a most important part in the general mortality. In cases which go on to cure, about 54 per cent according to Grissel, there is rapid improvement following surgical interference. The statistics of Makius and Abbott[31] show

71 per cent, those of Donati, 48 per cent, those of Volkmann, 41.8 per cent total mortality, all cases and all types of the diseases being considered. Osteomyelitis of the neural arches gives a much better prognosis than that of the body of the vertebra. The mortality for the latter is, according to Donati, 78 per cent, while that of the arches is only 35 per cent. Of the different sections of the spine osteomyelitis of the lumbar spine is more severe; while infection of the cervical bodies gives the best prognosis. Also sacral osteomyelitis is unfavorable because of the deep seat of the disease and the difficulty of its detection, as well as because of the size of the abscesses and their extension into the retroperitoneal spaces. Mayet and Duchamp de Lageneste[34] estimate the mortality of osteomyelitis of the vertebrae for the lumbar spine at 76 per cent, for the dorsal as 60 per cent, and for the cervical at 29 per cent.

Early diagnosis is of the utmost importance for the prognosis because it opens the possibility of timely and energetic surgical interference. In contrast to osteomyelitis of the long bones, that of the spine has a tendency to rapid repair as soon as the abscess is opened and free drainage is procured. Recurrences, however, are not uncommon.

B. SUBACUTE FORM OF OSTEOMYELITIS (PLATE LXVI, 1, 2)

1. Prognosis.—Subacute osteomyelitis of the spine is much less frequent than the acute form. Its prognosis for life and cure is much more favorable than that of the acute type. In this type, also, the most severe cases are those in which the vertebral bodies are involved; and here, also, the evacuation of the abscess and the occasional removal of the sequestrum results in rapid healing.

2. Complications.—Subacute osteomyelitis of the cervical vertebrae often extends to the meninges and produces meningitis, or, by extension in front, causes a retropharyngeal abscess.

In subacute osteomyelitis of the dorsal vertebrae the retropleural, and in that of the lumbar, the retroperitoneal abscesses appear as frequent complications.

The osteomyelitis in the bodies of the lumbar spine, also, opens the possibility of abscess formation in the psoas muscle and the iliac fossa, resulting in flexion contracture of the hip. Radiating pain over the abdomen, tenderness of the abdominal wall, and meteorism are observed as sequelae of retroperitoneal pus accumulations.

The nervous complications in the subacute form likewise depend upon the level of the disease, and are much more frequent in the cervical spine than at other levels. They may assume all degrees from the simple irritation of the spinal cord with hyperesthesias, to complete compression, spastic or flaccid paralysis, or direct involvement of the spinal cord in form of myelitis.

C. THE CHRONIC FORM OF OSTEOMYELITIS OF THE SPINE

1. Statistics and Prognosis.—Knowledge of this form of vertebral osteomyelitis is still very scarce. It is much rarer than either the acute or subacute osteomyelitis, although a sharp distinction between acute, subacute, and chronic forms cannot be made. In a very thorough review of the literature Wohlgemuth found only a few cases of chronic osteomyelitis of the spine recorded up to 1895. Most of the cases belong to the later age, and according to Oehlecker,[39] who reported on seven cases, the 5th decade is the most frequently affected.

2. Pathology.—The primary focus is usually a staphylococcus infection, in some cases a furuncle. In one case reported, acute osteomyelitis of arm and leg, which had healed for four years, was the source of infection of the vertebral bodies. In all cases observed by Oehlecker the osteomyelitis was located in the vertebral bodies quite in contrast to the acute form in which a prevalence of the arches and spinous processes exists. The staphylococcus infection of the vertebral bodies leads a milder course, either from the beginning, or it may enter in a more chronic stage after a more acute onset. In a majority of cases the lumbar spine is the seat of the disease, as it is in the subacute form; only a few cases of dorsal spine osteomyelitis are reported.

Deformity is not very prominent, due to the fact that there is usually an abundance of new formation of bone which prevents the massive collapse of the vertebral bodies.

Abscesses.—Among the abscesses developing from chronic osteomyelitis of the lumbar spine, the psoas abscess is in the foreground. In other cases the abscess developing in the lumbar region extends along the crest of the os ilei. Such abscesses may often be mistaken for tuberculosis. A microscopic and bacteriologic examination, including guinea pig inoculation, is usually necessary in the chronic form of osteomyelitis of the spine to establish the diagnosis.

X-ray Findings (Plate LXVI, 2, 5).—As unreliable as one usually finds the x-ray examination in the early stages of the acute form, as useful and significant is it in chronic osteomyelitis. The most characteristic point which distinguishes this condition from tuberculosis is marked condensation of the bony structures quite in contrast to the atrophy which is seen in tuberculosis of the spine. The so-called tuberculous spondylitis which presents itself in the x-ray picture by marked sclerosis and formation of bone bridges should be eyed with suspicion, as it may reveal itself as chronic staphylococcus osteomyelitis.

Nerve Complications.—Among the nervous complications the spastic compression paralysis of the lower extremities is most important. Extension of the inflammation into the spinal canal causes peripachymeningitis with pressure symptoms of the cord.

Other complications observed are metastasis in the kidneys and in the joints, especially in the hip joint.

VII. Treatment of Osteomyelitis of the Spine

Whether acute or chronic, the treatment of this condition is prevailingly surgical. Mathieu[32] and most of the other observers are very strong advocates of immediate surgical intervention. The surgical interference is directed toward the evacuation of the osteomyelitic focus in the bone as well as toward the drainage of the abscess.

Among sixty-three operations for vertebral osteomyelitis collected by Grissel,[17, 18] forty consisted in simple incision of the abscess. Although such an incision may suffice in a case where the infection is located at the posterior arch, one should always try to reach the osseous focus as the best means to prevent grave complications and to render the drainage broad and sufficient.

1. Operations upon the Spine.—The operation upon the bone consists in either simple curettement, in some cases in transversectomy and drainage, or, in a more extensive resection.

Curettage and partial resection suffices usually in cases where the lesion is limited to the posterior arch. In cases, however, where the seat of the disease is in the vertebral bodies, superficial or deep, it becomes necessary to attack the bodies themselves. This can be done by a posterior or a lateral route. The posterior route is necessarily preceded by a laminectomy.

The lateral route is more rational and relatively simple, but becomes more complicated in the dorsal spine because of the presence of the ribs and the danger attendant upon the vicinity of the pleura. In the cervical region it is complicated by the neighborhood of the nerves and vessels.

Approaches to the Vertebral Bodies. a. Lumbar.—For the lumbar region, Treves recommends an incision along the external border of the sacrospinalis muscle, reaching the vertebral bodies through the lateral aspect. Others recommend the exposure of the laminae first, reaching the lateral surface of the body aferwards, in order to avoid important structures.

The technic as described by Mathieu is as follows: a longitudinal incision is made through the skin, aponeurosis, and muscle bundles, a finger's breadth from the line of the spines. Exposure of the vertebral laminae follows until the transverse processes are exposed and the latter are resected at their base. Then the exposure of the lateral surface of the vertebral bodies is possible.

b. *Dorsal.*—In the dorsal region the approach to the vertebral body necessitates costotransversectomy; that is, the removal of the transverse process with the adjacent portions of the ribs, head, and neck, either unilaterally or bilaterally, according to the localization, extent, and the acuteness of the condition. When an extensive lesion of the body is expected, a bilateral costotransversectomy is indicated (for the technic of costotransversectomy as well as that of laminectomy, see Tuberculosis of the Spine, Chapter VI).

c. *Cervical.*—For the cervical region there are two routes of approach; namely, in front of the sternocleidomastoid muscle and behind it. The incision along the posterior border of the sternocleidomastoid is the most rational, and anatomically the most correct one.

One easily identifies the scaleni and, following their origin from the anterior and posterior tubercles of the transverse processes respectively, one has no difficulty in exploring the anterior surface of the vertebral body.

Drainage of the vertebral bodies after the resection of the transverse process by trocar is a method suggested by Mayer.[33] The trocar is inserted in an oblique direction following closely the contours of the body. Great care must be taken to avoid the important vessels lying in front of the vertebral bodies.

2. Drainage of Abscesses.—

a. *Retropharyngeal Abscesses.*—Such abscesses, if they occur in osteomyelitis of the spine, should be opened through the posterior pharyngeal wall only in cases of emergency. Otherwise it is better to drain through the lateral triangle of the neck. The best approach for this purpose is also from the posterior border of the sternocleidomastoid muscle. (For the technic of this approach see Tuberculosis of the Spine, Chapter VI.)

b. *Drainage of Prevertebral and Mediastinal Abscesses.*—These abscesses are reached by resection of the costotransverse articulations. The best approach is the classical costotransversectomy as used in cases of effusion of the pleural cavity and in retromediastinal abscesses following Tuberculosis of the Spine (see Chapter VI).

c. *Drainage of the Psoas Abscess.*—This is best done by an anterior incision such as practiced for the ligation of the common iliac artery. One must carefully avoid the puncturing of the peritoneum.

d. *Drainage of the Presacral Abscess (Plate LXVI, 4, 5).*—Here, one may use to advantage the technic of Picqué, which consists in total or partial resection of the sacrum.

The writer has used this method in several cases with the result that satisfactory drainage was established. This method also offers a good approach in osteomyelitis of the 5th lumbar and in sacroiliac osteomyelitis.

e. *Drainage of Intraspinal Abscess.*—Laminectomy will be necessary in all cases in which the disease is located in the neural arches. It also must be carried out in the presence of an epidural abscess.

In operation upon the bodies of the vertebrae by posterior approach, the dura must also be exposed by laminectomy for a certain distance. Here, the question arises whether or not the dura should be opened. This should be done only in cases where subdural suppuration is present, and it must be preceded by an exploratory puncture to make sure of the presence of pus under the dura. The opening of the dura must be attended by the usual precautions. If the subdural space contains pus, the dura should be opened over a long distance and compression of the dura should be carefully avoided.

Drainage of the Spinal Canal by Trocar (Method of Calvé[3a]).—Calvé uses a trocar which he introduces into the intervertebral foramina, thereby reaching the interior of the spinal canal. (For the technic and the statistics of this operation see Tuberculosis of the Spine, Chapter VI.)

3. **After-Treatment.**—Rest and immobilization are as important factors in the healing of osteomyelitis of the spine as they are in infections of the extremities. Following Orr's[41] principles of wide drainage and absolute immobilization, drainage of osteomyelitic foci of the dorsal or lumbar spine should be followed by immobilization in a plaster cast, which, in lumbar or sacral disease, should be extended over both thighs. The wounds are loosely packed with vaseline, and, provided the drainage has been carried out adequately, no dressings are required for the first few weeks.

D. OSTEOMYELITIS OF THE RIBS (PLATE LXVI, 6)

1. Statistics

Osteomyelitis of the rib is not so rare as generally assumed. Among 1328 cases of osteomyelitis collected by Michelson (1922), 1.43 per cent showed involvement of the ribs. Up to that date sixty-four cases were reported in the literature, to which Michelson added sixteen of his own. Infants and small children predominate. After the fifth year the frequency of osteomyelitis of the rib decreases; it is again more frequently seen in the 3rd decade.

2. Pathology

Located usually at the sternal end or at the angle of the rib, it produces a central necrosis or purulent foci, in which the staphylococcus areus is most commonly found, more rarely the streptococcus. The pus may burrow its way under the pectoralis muscles and appear in the axilla, or it may extend downward between the abdominal muscles. After the seventh year of life osteomyelitis is found more often in the posterior portion of the rib (Philardeau[43]).

3. Symptoms

The symptoms are dull pain in the chest, increased on movement in various directions. The pain becomes more definitely localized, swelling and edema appears and abscess develops at the thorax or in the back. Pus accumulates between the ribs and frequently wanders along the fascial layers until it appears in front of the pectoral muscles or behind, in the dorsal region.

The most frequent complications are empyema, and ulcerations of the intercostal artery with hemorrhage.

4. Differential Diagnosis

For the differential diagnosis, pneumonia, neuralgia, rheumatism, typhoid osteomyelitis, as well as lymphadenitis and mastitis must be considered.

5. The Treatment

The treatment of osteomyelitis of the ribs consists in early drainage in acute cases, and in wide incisions and sequestrotomy in more advanced ones. The prognosis is good. Out of eighty cases reported from the literature by Michelson,[35] only nine deaths were recorded.

E. OSTEOMYELITIS OF THE STERNUM

Xiphoiditis

Nontuberculous, destructive, inflammatory lesions of the sternum are rare. Necrosis and ulcerations of the bone, more often of the xiphoid process, are observed from pyogenic infections. Narat[37] (1917) quotes seven cases of osteomyelitis of the xiphoid process with swelling and pain. Treatment consisted in removal of part of the xiphoid process. The x-rays in these cases were negative. The symptoms are those of pressure tenderness, pain, redness, and swelling. Abscesses arising from the posterior sternal wall (retrosternal abscess) cause difficulties in breathing, cyanosis, etc. Abscesses at the anterior surface are readily recognized by the edematous, later phlegmonous, swelling over the sternum and the adjacent portions of the ribs. The treatment is always surgical.

F. ACTINOMYCOSIS OF THE SPINE (PLATE LXVII, 1, 2)

Reviewing the literature up to 1923, Parker[42] finds only eleven cases cited of actinomycosis of the spine, to which one unreported case of his own was added. This small number shows that its recognition is still difficult. The clinical symptoms are those of chronic osteomyelitis of the spine and it is usually not possible to make the diagnosis unless the characteristic sulphur granules are found in the sinuses, which appear in considerable numbers over affected portions of the spine. Spinal symptoms appearing in the patient who is suffering from actinomycosis, naturally suggest the latter as the cause of the spinal disturbances.

In a case coming recently under the writer's observation (courtesy of Dr. H. L. Beye) the disease started with subacute symptoms in the cervical spine: pain, swelling and the formation of abscess.

No differentiation between tuberculosis or chronic osteomyelitis could be made from the x-ray picture.

At autopsy numerous sulphur granules were found. The spinal lesion consisted in erosion of the body and vertebral arches (Plate LXVII, 1).

In Parker's case there was an erosive process found which extended through the bodies to the posterior surface of the 3rd, 4th, and 5th lumbar vertebrae A large cold abscess surrounded the entire lumbar spine and extended downward to psoas muscles and inguinal region. The microscopic sections of the granulations surrounding the vertebrae showed typical actinomycotic changes. There were large areas of bone destroyed by lacunar absorption and replacement by granulomatous tissue composed of round and epithelioid cells and degenerated tissue.

The prognosis of actinomycosis of the spine is grave, especially since spinal infection is usually secondary to other already developed primary foci. Of the cases collected in the literature by Parker all died with the exception of one case.

The treatment depends upon the orthopedic condition. If deformity exists protective measures must be used as in Pott's disease. For compression symptoms of the cord, laminectomy is indicated. Curettement of the bodies of the 2nd and 3rd dorsal vertebrae was done by Guleke, and this case presents the only recovery on record.

Blastomycosis

Blastomycosis (yeast germ) of the spine is also a most unusual condition. According to Parker there were, up to 1914, twenty-nine cases collected from the literature (Stober) of pyemia caused by yeast. Of these, six cases involved the spine: five of these the vertebral bodies and in one the laminae were involved; two showed involvement of the spinal cord.

The condition is as malignant as actinomycosis of the spine. In all instances reported the patients died.

G. THE TYPHOID SPINE

1. Historical

Although the first account of the typhoid spine is usually ascribed to Quincke[45] (1899), Keen (1876) gave a full description of thirty-seven cases of bone lesions following typhoid fever, seven of which involved the spine. Gibney[15] (1889) reported four cases of spinal disease following typhoid fever, using the term perispondylitis, by which he inferred an acute inflammation of the periosteum and of the fibrous structures of the spinal column. These observations have been later corroborated by the experiences of Ridlon, Steele, and others.

Taylor distinguished three distinct conditions which develop in the spine in the wake of typhoid fever: One is a true perispondylitis (Gibney's type); another a painful condition of muscles, and a third a hypersensitive, so-called neurasthenic spine. He considered this an organic skeletal lesion of typhoid nature and called attention to the peculiar absence of suppuration in this disease.

2. Pathogenesis

The presence of typhoid bacilli in the spine established by Fraenkel[12] in 1903 identified the disease as the true typhoid complication. Fraenkel examined microscopically the lower dorsal and upper lumbar vertebrae of thirteen patients dead from typhoid fever and found typhoid bacilli in the marrow of ten cases. His findings were not always uniform and not regularly encountered in all vertebrae. The microscopic examination of these vertebrae showed necrosis, hemorrhage, giant cells, lymphocytic infiltration as well as typhoid bacilli. This author concluded that the marrow changes begin in the first stages of typhoid and reach into the convalescent period. From the beginning the patient harbors multiple typhoid foci in the bone marrow which either become retrogressive and symptomless, or, under cer-

PLATE LXVII

Fig. 1.—Actinomycosis of cervical spine. (Note mottled areas in bodies and spinous processes. Death of streptococcus meningitis.)

Fig. 2.—Actinomycosis of the spine (Boström).

Fig. 3.—Typhoid spine (Haselhorst).
(A) Narrowing of disc and proliferation.
(B) One month later. (Note bone condensation, narrow disc, and rapid regression of lesion.)

Fig. 4.—Approach for division of occipital nerve (courtesy Dr. H. J. Prentiss).

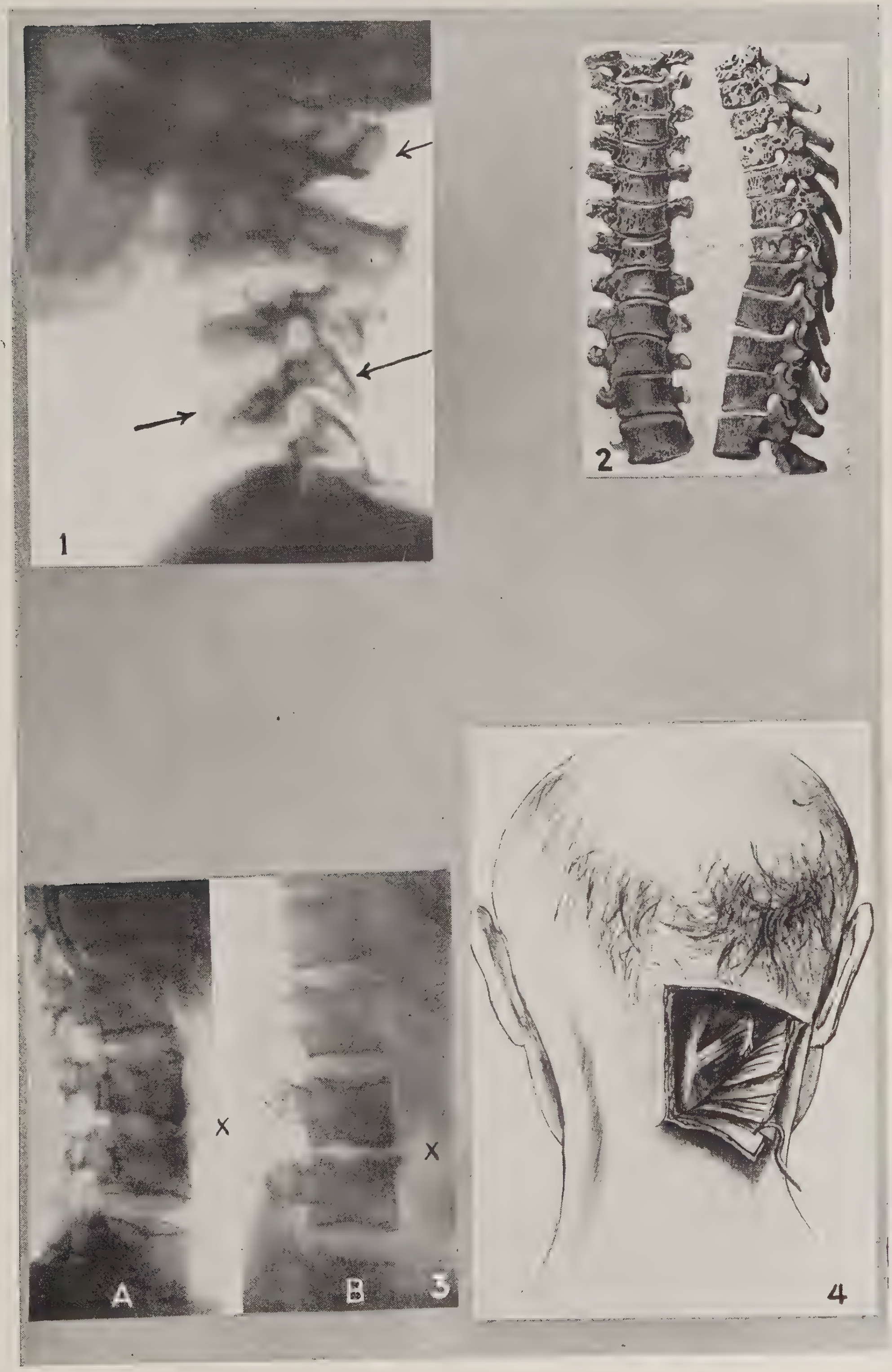


PLATE LXVII

tain conditions, become manifest. The latter is the case where there is a special accumulation of bacilli and particularly if a contributory cause supervenes, such as trauma or exertion, or too early resumption of occupation.

Typhoid bacilli in an abscess of the thigh were found by Busch[3] as late as twenty-three years after the infection.

3. Pathology

The condition is essentially an osteomyelitis located at the periphery of the vertebral body. Especially under the longitudinal ligament and near the intervertebral discs the osteomyelitic changes are found. The spinal nerves issuing from the foramina become involved in inflammatory infiltration and edema. The most striking feature is the disappearance of the intervertebral discs, which leads to approximation and finally to synostosis of the vertebral bodies above and below. The lordotic lumbar section of the spine is the most frequently affected and the vertebral destruction leads to effacement of the lordosis, or even to a kyphotic deformity. It is only in severe cases, however, that actual destruction of the interior of the vertebral body occurs, so that a collapse kyphosis is produced. In most cases the process stops with fusion of the vertebral bodies after the intervertebral discs have become destroyed. In a case described by Rough the intervertebral disc was missing and was replaced by bony overgrowth resembling the bone tissue of the vertebral bodies. Microscopically there was absence of the cartilaginous tissue and very marked overgrowth of dense connective tissue rich in blood supply. This connective tissue bridges the space normally occupied by the intervertebral disc.

4. X-ray Findings (Plate LXVII, 3)

The most striking feature is the already described disappearance of the intervertebral disc. It first becomes narrow and finally completely disappears. X-rays taken seven weeks after onset of the typhoid already show a shadow completely filling the intervertebral space between the 4th and 5th lumbar vertebrae, according to Conner, and other observers confirm this observation of the early disappearance of the disc. The intervertebral space is filled by marginal osteophytes and bone bridges, which form concurrently with atrophy and absorption at the edges of the vertebrae (Haselhorst[22]). The finished process is the total disappearance of the discs and complete fusion of the vertebrae.

The changes in the bodies themselves as seen in the x-ray picture are less striking. There are also signs of ossification of the longitudinal ligament aside from the bone bridges from vertebra to vertebra, which span the intervertebral space. Neither the disappearance of the disc nor the bone bridges, however, are strictly pathognomic; the same changes can be found in hypertrophic arthritis and occasionally in tuberculosis. Suggestive is the localization in the lumbar spine, and the fact that the disc disappears much more rapidly than is usually the case in arthritis or in tuberculosis, and that there are no similar changes in other sections of the spine.

5. Clinical Symptoms

Typhoid spondylitis is characterized by the relative benignity of infection which tends to take a subacute course; by the period of latency between the onset of the disease and the appearance of the spine symptoms, and finally by the absence of suppuration. The interval between typhoid and the spine symptoms varies from a few days after the fall of the temperature to weeks and even months. The onset is usually insidious without elevation of temperature or any general reaction (Murphy[36]). Occasionally, however, there is a rise in temperature after a free interval, but the fever, though it may be high, usually subsides in a short time (Wullstein[53]). The most characteristic symptom is the violent pain in the back appearing during convalescence, and involving principally the lumbar spine. The pain radiates into the groin, the abdomen, the lower limbs, and often follows the lumbar plexus and obturator distribution. Pressure pain is very distinct over the spines of the lumbar section and over the long muscles of the back. Contracture of these muscles produces attitudes of lordosis or scoliosis. Signs of root pain present themselves in form of hyperaesthesias which correspond mostly to the 2nd to 4th lumbar distribution. The cause of these Quincke believed to be inflammatory infiltration and edema of the intervertebral foramina and to periosteal thickening. The rigidity of the spine which appears as an early symptom of spinal involvement goes on to complete stiffening.

True gibbus formation is the exception; it occurs only in severer cases. Freiberg[14] observed gibbus following pain and rigidity. As a rule, however, weeks or months elapse before a change in the configuration is noticed. Whether such deformation is due to actual destruction in the anterior portions of the bodies with subsequent collapse as Wullstein believes, or is merely the effect of the destruction of the intervertebral discs, is uncertain.

The average period of latency between the first appearance of fever and of spinal symptoms is from three to five months.

6. Differential Diagnosis

The principal conditions which enter into the differential diagnosis are:

(a) Spondylitis Deformans.—Here, points of semblance are the pain and pressure symptoms, the stiffness, sometimes also the localization, as in the Strumpell-Marie type.

Points of differentiation are absence of typhoid history, involvement of other joints, the distribution of the spinal symptoms, and finally the x-ray pictures (see Chapter IX).

(b) The Low-back Sprain.—Here, the point of semblance is the pain and its distribution in the lower spine, the rigidity, and the muscle spasm. The diagnosis is determined by the history of the onset, the absence of definite x-ray findings, the characteristic restriction of motion, the local signs of strain and the attitudes of relief (see Chapter V).

(c) Tuberculosis of the Spine.—This condition resembles typhoid fever in the onset, in the circumscribed localization and in the rigidity of the spine. It is differentiated from it, however, in the history, in the type of the local pain which is less intense, in the radiating pain, and above all, in abscess formation which is uncommon in typhoid. The x-ray picture also shows gross destructive lesions of the vertebrae. Finally the kyphosis or gibbus seen in tuberculosis is an uncommon deformity in typhoid spine.

(d) Neurosis.—Neuroses manifest themselves by a generalization of symptoms, which are of uncertain and vague character and do not include well-defined pressure pain and radiation as in the typhoid spine. General neurotic habits, history of a trauma or shock, and the instability of the nervous system in general, point toward neurosis. Neurotic patients are not relieved by immobilization. On the other hand, typhoid may be an antecedent of nervous irritability and in such cases the differential diagnosis becomes difficult. Here it may be recalled that Osler considered the typhoid spine as a neurotic condition.

7. Prognosis

The prognosis in general is favorable. After a few weeks the infiltration recedes and the local symptoms of pain and tenderness improve. The outcome is usually the recovery of considerable mobility of the spine and most of its stability. Ely,[9] in his own case, reports cure with considerable rigidity; in other cases the persistence of the gibbus is reported.

8. Treatment

Severe pain after an attack of typhoid should be recognized as spine complication; the patient should sleep upon a firm bed; the maintenance of absolute rest should be observed until all pain has disappeared (Murphy). Slight cases recover under bed rest and recumbency. Violent pain is best controlled by absolute immobilization in a plaster bed which is made preferably in reclination (Wullstein). When the severe subjective symptoms have disappeared, which is usually the case after several months in bed, the patient is then allowed to be up in the leather or celluloid jacket.

Opiates should be avoided, if possible, in view of the protracted course of the disease.

The use of autogenous or stock vaccine during the painful stage is recommended (Murphy). Foreign protein administered intravenously, 150 million of dead typhoid bacilli, causes a marked reaction in leucocytosis (20,000). O'Donnell[38] reports very striking results from its use; the pain was noted to disappear on the following day.

H. THE TYPHOID RIB

Helferich (1890) was the first to describe a chrondritis of the ribs following typhoid fever similar to the osteochondritis of the rib appearing in other acute infections, such as influenza. This suppurative inflammation of the costal cartilages is not an uncommon occurrence in typhoid and typhus fever. Busch[3] observed twelve cases which occurred three to eight weeks after the beginning of convalescence. Among forty-two cases of costal caries secondary to acute infections, Jassenetzki-Woino[25] observed fifteen after recurrent fever, eight after typhoid, five after typhus, and fourteen after other infections.

1. Pathology

The inflammation begins as an osteomyelitis of the marrow of the rib (Oppokoff and Odojewsky[40]). According to Popow[44] the costal cartilage, up to fifteen years, is milky white with scarcely perceptible bluish strips through it (capillaries). In the ages from fifteen to twenty these central blood vessel canals become more and more numerous and after twenty to thirty years they are seen, after the removal of the perichondrium, in greater numbers. These canals contain masses of loose connective tissue, blood vessels, and can be considered as marrow spaces. At this age the vascularization of the cartilage increases from the upper to the lower ribs, being most definite in the cartilage of the lower ribs; and after fifty years of age retrogressive changes again take place in the vascularization of the ribs and the bone elements become atrophic, and the vascular canals obliterate. Therefore, it can be understood that the cartilage of the lower ribs (6th to 9th) are more frequently involved than those in the upper, in the chondritis which follows typhoid or paratyphoid, or other bacteremias (Linberg[30]).

The pathologic anatomic changes consist either in chondritis in the interior of the cartilage, or in perichondritis. In the first, intrachondral cavities are formed and the perichondrium is engaged secondarily. In the latter the process starts from the perichondrium which melts away, leaving the cartilage bare. The intrachondral abscess perforates into the soft tissues and forms a superficial abscess and finally establishes a sinus. When secondary infection supervenes, the process is likely to spread over neighboring cartilages, causing there perichondritis with denudation and necrosis of cartilage.

In the cases of Busch 5 to 10 ribs were involved. Fitts reports a case with destruction of the anterior ends of the 4th, 6th, and 7th ribs and their corresponding cartilages, five months after typhoid.

2. Symptoms

The symptoms are ushered in by pain along the costal cartilage, followed, after days or weeks, by the formation of a hard tumor. This swelling persists for a long time, and sometimes softens and breaks in the center, issuing a bloody purulent matter. The purulent material obtained from the sinuses shows typhoid bacilli and gives a positive Widal test.

3. Treatment

The treatment is surgical. Early incision and drainage of the abscess and removal of sequestra or small necrotic débris is indicated. Under this treatment cure is usually effected. One must be careful, however, to operate radically enough. Not only the diseased cartilage, but also the neighboring sound cartilage must be resected.

I. COMMENT ON CHAPTER VII: OSTEOMYELITIS OF THE SPINE

As in osteomyelitis in general, so also in that of the spine the great problem is earliest possible drainage. Consequently every effort must be bent upon early recognition.

In the acute form, so far as it involves the vertebral bodies, great difficulties arise, both as to early diagnosis and the adequate drainage. Drainage of the bodies in the dorsal spine is best accomplished through laminectomy.

The situation becomes much better in the acute form involving arches and pedicles, which is, fortunately, the more frequent one. Here, both recognition and drainage are easier; consequently the mortality is considerably lower.

The para- and prevertebral abscesses, as well as those in the retromediastinal and retroperitoneal cavities, which form rapidly in cases surviving the shock of general septic infection, likewise need radical and speedy evacuation and the methods described for use in infected tuberculous abscesses of this kind serve well in this condition, also. Early and adequate drainage together with postoperative immobilization are the fundamentals of the treatment.

As we turn to the subacute and chronic form of vertebral osteomyelitis, we find the chances for recovery greatly improved and especially so in the chronic types of typhoid and paratyphoid nature. In the latter, abscess formation is unusual, the pathologic changes are prevailingly formative. Immobilization, consequently, is the main issue.

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CHAPTER VIII

SYPHILIS OF THE SPINE

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I. SYPHILIS OF THE SPINE: SPONDYLITIS SYPHILITICA (LUETICA)

1. Frequency and Site

As a manifestation of tertiary syphilis of the spine, where it is much less frequent than in other parts of the skeleton, vertebral lues shows a distinct preference for the cervical section.

Fifty-five cases reported in the literature up to 1904 had the following distribution (Neumann[18]): thirty-six affected the cervical, nine the dorsal, eight the lumbar, and two the sacral spine. Ziesche's[29] analysis of 1911, embracing eighty-eight cases, shows the following localizations: cervical spine, sixty-one, dorsal spine, twelve, lumbar spine, five, sacral spine, two, cervicodorsal spine, one, dorsolumbar spine, three, and diffuse, four; 70-80 per cent of all cases on record are afflictions of the cervical spine.

2. Pathology

a. Fetal Syphilis.—Syphilis in the spine of the fetus has been observed and described. It seems that syphilis does not impede the regular appearance of ossification centers. Normally, the ossification of the arches starts from the atlas downward, while that of the body starts from the dorsolumbar level in both directions. According to Alexander,[1, 2] who examined a specimen showing the characteristic luetic disturbances of the epiphyseal lines, ossification was not affected in the bodies of the atlas but showed distinct changes in both neural halves; whereas, in the same spine, in the sacral region the luetic picture appeared in the ossification centers of the body while the arches were free. It seems, therefore, that the development of ossification and syphilitic changes in the fetus are interdependent.

b. Congenital.—Congenital syphilis of the spine occurs regularly as osteochondritis or periostitis syphilitica, also starting from the zones of ossification (Jürgens[15]). The surgical interest in congenital syphilis of the spine is rather limited as the disturbance of ossification does not lead to extensive deformation nor does it produce clinical symptoms. The occurrence of a vertebral localization of hereditary lues has long been doubted, but Neumann,[18] who demonstrates the existence of congenital lues of the spinal column, cites four cases between the ages of four and eleven years.

Ridlon[20] believes that syphilitic spondylitis in very young children is not at all uncommon. In children under three years of age, if associated with chronic disease of other joints, or if separate foci within the spine are present, the affection is more likely to be syphilitic than tuberculous; other syphilitic manifestations such as the nasal catarrh, corneal scars, and interstitial keratitis, or other stigmata, are often revealed upon careful examination.

c. Acquired Form (Plate LXVIII, 1).—In contrast to tuberculosis, acquired syphilis of the spine is a rare disease. It manifests itself in a variety of pathologic formations: Periostitis gummosa was first described by Volkmann as multiple, circumscribed syphilitic lesions of the spinous processes. Fournier[9] described the isolated hard gumma situated behind the larynx at the anterior wall of the spine, and others again called attention to diffused gelatinous infiltration which is seen in the lower half of the dorsal segment and the lumbar section of the spine, and which so often causes compression of the cord.

We know now that the pathologic lesions found in syphilitic arthritis of the spine are the same as found elsewhere in skeletal syphilis. The acquired

PLATE LXVIII

Fig. 1.—Gumma involving spine.

Fig. 2.—Charcot spine. Destruction of 1st, 2nd, and 3rd lumbar.

Fig. 3.—Charcot spine. Destruction of 5th lumbar causing list.

Fig. 4.—Charcot spine and hip. (Fusion of hip resulted in stable joint.)

Fig. 5.—Charcot spine detail of Fig. 4. Occurrence of bridging.

Fig. 6.—Charcot spine (fusion of 2nd, 3rd, and 4th lumbar).

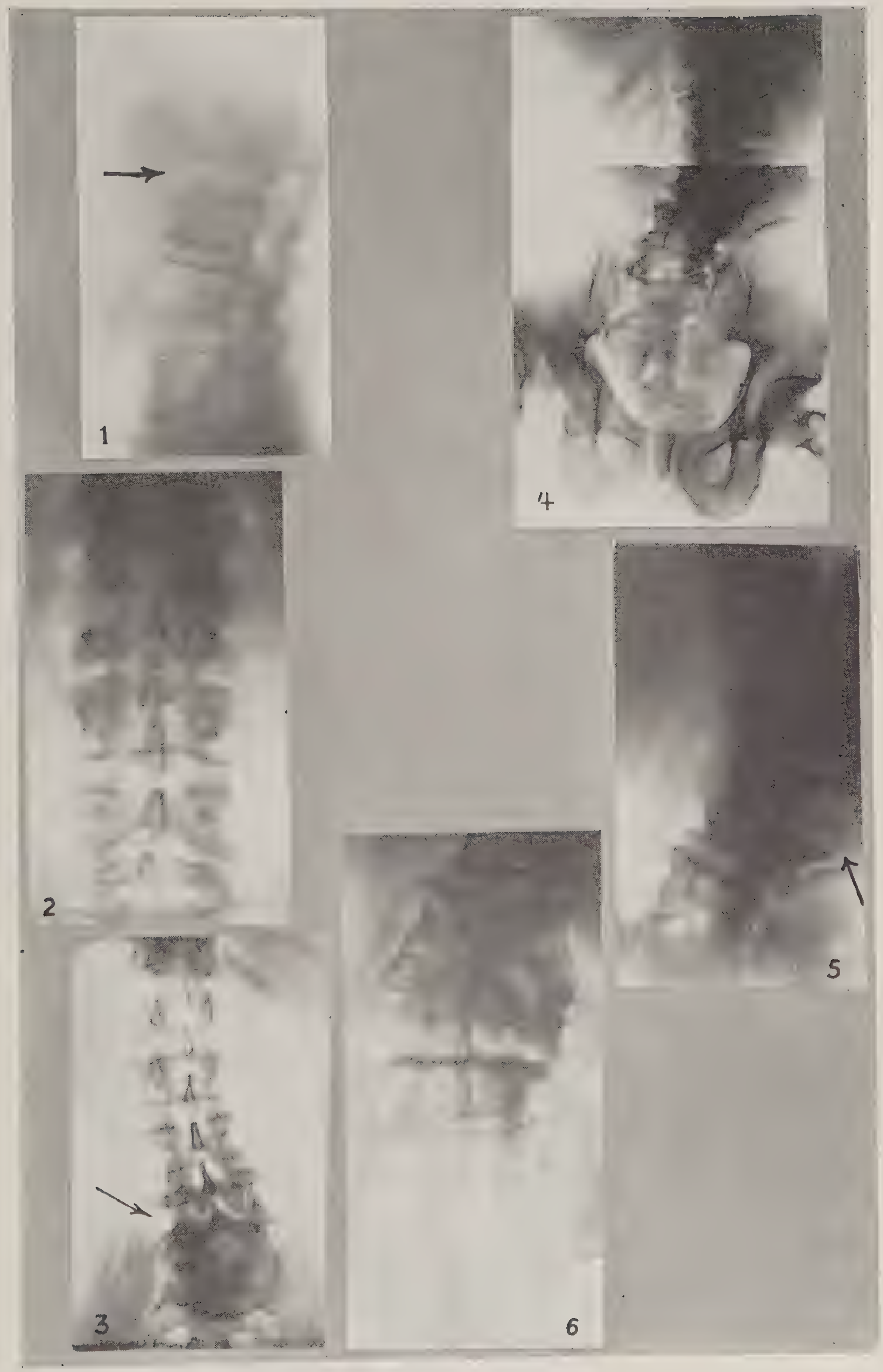

PLATE LXVIII

forms involving the vertebrae almost always belong to the tertiary stage. Occurring many months or years after the primary lesion, the changes consist in exostoses, gummatous production, periostitis and osteomyelitis, with occasional necrosis and sequestration of bone. Tendency to pus formation is slight, and cold abscesses such as found in tuberculosis do not occur.

The greater number of the cases involves the cervical spine. Numerous instances are reported of gummatous destruction of the body of the atlas associated with ulceration at the posterior pharyngeal wall (Brown[3]). In a case cited by Neumann[18] there was found necrosis of the 1st and 2nd cervical and dislocation between the 3rd and 4th cervical vertebrae, with suppuration, an unusual occurrence in luetic spondylitis, spreading to the pleura and lungs; there was also the characteristic large ulcer at the posterior pharyngeal wall.

According to Koenig[16] syphilis of the spine is only rarely associated with deformity. Obviously the bodies of the vertebrae, in the presence of a gumma, do not collapse. Still, kyphotic deformity in luetic spines is not unknown and there are several cases reported (Leyden[17]) in which such deformities were found.

An almost characteristic feature of syphilis of the cervical spine is the sloughing of the articular portions of the body of the atlas or of the odontoid process of the 2nd vertebra. Very often it comes to the sloughing of the articular facets from the anterior surface of the odontoid process, and to sequestration and extrusion of the sequestrum through the pharyngeal ulcer. The first case of this kind is described by Wade[25] in 1845. Brown[3] records from the literature five cases of syphilitic exfoliation of the 1st and 2nd cervical vertebrae. Another case of necrosis of the atlas is reported by Fischer.[8] It resulted in the expectoration of a long piece of bone, 2.5 cm. long, consisting of the entire anterior arch of the atlas.

In contrast to these cases of extensive bone destruction there are many others of acquired syphilitic spondylitis with quickly healing periostitis, though the majority of cases belong to the severer form.

d. Cord Changes.—The involvement of the spinal cord in luetic spondylitis consists in changes of the cord as well as of the meninges and spinal nerves. Compression signs are not infrequently caused by exostoses which protrude into the spinal canal. In other cases compression is produced by a gumma located in the canal. Finally, independent gumma formation within the spinal cord itself is not an unusual complication. On the part of the meninges pachymeningitis syphilitica is observed, due to extension of the process from the posterior wall of the vertebral bodies.

Involvement of the spinal roots in luetic spondylitis consists of sclerosis of the posterior roots and in demyelinization, resembling the changes seen in Tabes. Fibrous tissue is seen surrounding the roots and sclerosis is noted in the subarachnoid space (Claude[5]).

3. The Clinical Symptoms

The clinical symptoms do not differ essentially from those accompanying other affections of the spine (Hunt[13]). The principal features are pain, local and referred, rigidity, sometimes deformity, and signs of compression or inflammation of the spinal cord. Occasionally there is found swelling of the regional lymph glands, or disturbances in breathing and deglutition when the upper cervical spine is involved.

a. Pain.—

(1) *Local.*—Pain is noted upon pressure upon the spine as well as upon motion and upon concussion.

Spontaneous pain very often is violent and changing in intensity. It is of characteristic nocturnal and osteocopic type.

(2) *Referred Pain.*—Neuralgic complications are frequent. Analyzing one hundred cases from the literature Hunt[13] found neuralgic symptoms present in twenty-six. Fourteen of these were cervical, three dorsal, four lumbar and two sacral. Fourteen of these cases indicated lesions of the spinal cord, i.e., compression myelitis.

(3) *Radiating Pain.*—Radiating pain is frequently encountered in luetic arthritis of the cervical spine, where it often follows the run of the greater occipital nerve. It is also seen in the lumbar spine, causing neuralgic pain in the lower limbs.

b. The Rigidity.—The rigidity of the luetic spine resembles that encountered in tuberculosis. In involvement of the cervical vertebrae the head is held in forward flexion simulating suboccipital disease. When the lumbar spine is involved, the body is thrown backward by the contraction of the long muscles of the back.

c. Deformity.—An angular deformity or gibbus is not commonly observed. Joachimsthal[14] describes the disappearance of a gibbus after antiluetic and orthopedic treatment. Such an occurrence is probably due to the release of muscular contracture and is also facilitated by the characteristic new formation of bone in luetic arthritis which offsets the gummatous destruction.

d. The Cord Symptoms.—Cord symptoms consisting in increased reflexes and spasticity are observed. Compression of the spinal cord results in spastic paraplegia. To the medullary signs radicular symptoms are often added: hyperesthesia and paresthesia. Atypical cord symptoms have been observed. Dejerine[7] describes a case with motor paralysis on one side and sensory disturbances on the other (Brown-Sequard's syndrome).

e. General Luetic Symptoms.—In hereditary syphilis one usually finds the characteristic stigmata: the Hutchinson's teeth, the interstitial keratitis, nasal catarrh, pharyngeal changes.

In acquired syphilitic spondylitis the Rhomberg sign and positive Wassermann reaction are most frequently observed. A positive Wassermann reaction, while very suggestive of the luetic character of the spondylitis, does not always determine it, and vice versa, the negative Wassermann test is not a definite sign of the absence of the syphilitic spine lesion. In the majority of cases, however, about 75 per cent, the Wassermann reaction is found positive.

4. The X-ray Examination

Gummatous destructions in the vertebral bodies present themselves as round, sharply defined defects in the bone, scooped out shadows, seen most commonly in the cervical spine.

Hypertrophic bone changes appear as sclerosis or periosteal hyperostoses and have no pathognomonic significance, except if confined to the cervical spine, when they become suggestive of the specific nature of the disease. Sequestration of larger pieces of bone, for instance, in the cervical region, is readily demonstrable in the radiogram.

Angular deformity is rare because the limited destruction of the body and the extensive hypertrophic changes prevent spinal collapse. As an exception Van der Hoop[24] reports x-ray findings of angular kyphosis involving the 9th to 11th dorsal vertebrae.

5. Differential Diagnostic Points Regarding Tuberculosis of the Spine

The history of a previous luetic infection is of greatest importance. The luetic spondylitis usually follows in early years after the primary lesion.

The positive Wassermann reaction has already been mentioned as a suggestive but not absolutely deciding factor, and, while it was stated that the negative reaction does not necessarily exclude the syphilitic character of the lesion, a combination of syphilis and tuberculosis must be considered. Suggestive for the syphilitic character of the lesion is the intermittent pain, with nightly exacerbations. Tuberculosis, furthermore, is found more often in children while syphilis is more frequent in adults and in older people. Still, it is variously stated that a number of cases of apparent Pott's disease in younger children, in which other joint involvement exists, are syphilitic (Ridlon[20]). Absence of cold abscesses is more peculiar to lues. The diagnosis is often made only from the effect of antisyphilitic treatment.

6. The Treatment

The general antiluetic measures commonly in use are potassium iodide, salvarsan, and mercury. In addition to these, orthopedic measures for the support of the spine are indispensable. In more acute cases with a great deal of pain, recumbency combined with traction, is indicated. It is likewise required in the presence of signs of spinal compression.

In the ambulatory treatment the policies prevailing for tuberculosis of the spine apply to this condition also. That is to say, it is conditional upon disappearance of acute signs and especially of compression signs.

For the support of the spine and especially for the control of the very disturbing backache (Roberts[22]), plaster jackets or braces, properly constructed, are very effective (see Chapter VI). In cervical disease and also in that of upper dorsal, all supporting appliances must include chin and occiput.

II. ARTHROPATHY OF THE SPINE (CHARCOT SPINE)

1. Historical

It was Charcot[4] who first (1868) described tabetic arthropathies of the spine. His classical description was followed by the publications of Krönig and others, in which the syndrome complex of tabetic arthropathy of the spine was developed. Involvement of the spine in the tabetic process was considered to be a great rarity. According to Funsten[10] there were, as late as the beginning of the 20th century only fifteen cases on record, and only one of these from an American observer (Cornell[6]). Twenty-six cases were collected by Frank in 1904. Nevertheless, the condition cannot be considered exceptional. Literature reports have greatly increased in the last decades, Ridlon and Berkheiser's[21] series alone embracing ten cases.

2. Pathology

a. Vertebral Bodies.—The first changes appear in the vertebral bodies (Wullstein[28]). They consist in atrophy of the lamellar structure of the spongious substance and of the corticalis. The bone marrow assumes a more embryonic character, the Haversian canals become enlarged, the organic substances in them, especially fat, are increased, while the inorganic substances become decreased. The picture is that of osteoporosis.

b. The osteoporotic bodies undergo deformation, a wedge-shaped flattening by compression. This wedge deformation leads to spinal deformity: sometimes to lordosis, but more frequently to kyphosis, scoliosis, or kyphoscoliosis, according to the portion of the spine involved, and according to the attitudes and postures assumed by the patient. These primary scoliotic and kyphoscoliotic curves invoke the formation of compensatory changes in other sections of the spine, and in the thorax and pelvis.

c. Bone Reaction.—Although the compact substance of the body of the vertebra is decreased, the vertebral bodies themselves become more voluminous, due to periosteal and parosteal bone reaction. This excessive formation of callus seems to be thoroughly unconcerned in any particular biologic law. It is irregular and develops in degrees beyond all the static and dynamic requirements. Articulations, as well as vertebral ligaments, take part in the formation of this excessive callus.

d. Reaction to Trauma.—In spite of the enormously increased bone production it seems that the tabetic vertebrae are very susceptible to trauma, and that a sudden breakdown of the vertebrae often occurs. This explains the apparently sudden onset of deformity or of subjective symptoms in the tabetic spines. It has a corollary in the acute onset of tabetic arthropathies in other joints (knees). One finds, on close observation, that this rapid onset is only apparent, in that it merely signifies the sudden collapse of the spine which has already been greatly damaged by pathologic changes. This also explains the rapid increases in the deformity described from time to time. Sometimes, displacement and abnormal motion of fragments persist after spontaneous fracture of the tabetic spine, owing to insufficient callus formation; more often, however, vertebral fractures in tabetic spines heal with normal or excessive formation of callus. All these abnormalities in bone reaction are due to trophic disturbances incident to the tabetic changes in the spinal cord. To these trophic reactions also belong the atrophic changes seen in the intervertebral discs, caused in response to compression and distension stresses.

The paravertebral ossifications are of the most striking nature. They occur with preference on, and in the anterior longitudinal ligament as well as in the interspinous ligament, and in the capsules of the small joints. The lawless irregularity of bone reaction is illustrated by a case of Oberndorfer:[19] the first and second lumbar were sclerosed. The lower part of the body of the first lumbar articulated with a rounded joint body into a broad socket formed by the second lumbar. Here, the intervertebral disc was completely destroyed. The third lumbar was greatly rarefied, the disc between the second and third lumbar was gone, the space being filled with islands of hyaline cartilage.

3. X-ray Findings (Plate LXVIII, 2, 3, 4, 5, 6)

The alternation between sclerosis and rarefaction, bone absorption, and bone apposition is the most striking feature in Charcot's spine. In some cases the destructive, in others the proliferative, changes prevail, often both are seen concomitantly, especially so in the fifth lumbar vertebra (Witkowsky[27]). In other instances there are osteophytes in the lower dorsal or lumbar spine, together with bone defects and signs of decalcification.

4. Clinical Symptoms

a. **Deformity.**—One of the earliest and most constant signs is deformity. It is, as a rule, ushered in by the breakdown of one of the lateral articulations of the vertebral bodies (Herndon[12]). As the bone destruction continues there follows compression of the vertebral body with posterior or lateral displacement. The process is usually limited to one or three vertebrae, and most frequently found in the lower dorsal and lumbar spine. The resulting deformity is usually a kyphos with more or less lateral curvature and rotation. The involved section of the spine is usually held rigid. There is no tenderness and no muscle spasm.

b. **Pain.**—Local pain is usually nocturnal and persistent. Considerable discomfort is often caused by pressure of the collapsing spine or that of hypertrophic bone formations upon the spinal nerves. These root pains are usually gradual and insidious in onset and of moderate severity; occasionally, however, they attain considerable intensity, sometimes simulating gastric crises.

c. Mobility.—It is peculiar to the tabetic arthropathy of the spine that the mobility of the spine is little involved unless in cases of excessive destruction. According to Ridlon and Berkheiser[21] who reported ten cases, the spine, as a whole, shows an excessive floppy mobility, with the exception of the circumscribed local rigidity over a limited section involved in callus formation.

d. Complications.—The most important complications are those of the spinal cord and spinal nerves.

Direct pressure symptoms of the spinal cord are unusual. Combination with the tabetic signs of spinal cord degeneration, however, is frequent, and one must distinguish between these and cord symptoms caused secondarily by compression. This applies also to the neuralgic symptoms, although true pressure neuralgia produced by the collapsing spine is more frequent than spinal cord complications.

5. Differential Diagnosis

a. Tuberculosis.—Here, also, the onset is slow and insidious, but the pain, and the destructive changes in the x-ray picture, the general reaction of the body, and the absence of general tabetic symptoms, characterize Pott's disease.

b. Spondylose Rhizomelique, Atrophic Spondylarthritis.—This is a more diffuse affection of the spine, while tabes is usually restricted to the lower dorsal and the lumbar spine. There is also a difference in the character and type of pain; and there is the involvement of other articulations peculiar to arthritis.

c. Malignant Disease of the Spine.—Malignant disease is characterized by uncontrollable pain. Deformity in metastatic tumors of the spine occurs late. Compression symptoms are especially noticeable in the malignant spine.

d. Typhoid Spine.—In typhoid spine the history and the great muscular rigidity as well as the x-ray picture in later stages are characteristic.

e. Fractures.—Fractures reveal themselves by history, although it must be kept in mind that the onset of the symptoms in Charcot's spine may be sudden and apparently follow trauma, when the latter, in fact, is merely a superinducing cause which leads to the collapse of the already diseased spine.

f. Paget's Disease.—In Paget's disease there are also marked vertebral changes, but other bones are involved and especially the changes seen in the skull and the long bones are characteristic.

6. The Treatment

The treatment of the tabetic arthropathy consists of the general antiluetic and antitabetic treatment and of local measures for support and immobilization of the spine. For this immobilization the plaster jacket as well as leather or celluloid corsets are suitable. In mechanical principles and in technical execution these apparatus differ in no way from those used for support in spinal tuberculosis (see Chapter VI), and for other afflictions of the spinal column.

III. COMMENT ON CHAPTER VIII: SYPHILIS OF THE SPINE

Luetic spondylitis is being diagnosed largely on circumstantial evidence (stigmata, history, Wassermann), rather than on local recognition. With the exception of the sharply cut gummatous defects of the vertebral bodies seen in the x-ray, and of the not frequent instances of necrosis of portions of the atlas and odontoid associated with ulceration of the posterior pharyngeal wall, there is little that is characteristic for syphilis of the spine.

Hereditary syphilitic spondylitis, the existence of which has long been doubted, seems to be an acknowledged fact. That it occurs more often than is generally believed is assumed by various observers, who consider many cases of apparent Pott's disease associated with other joint involvement in young children as luetic (Ridlon).

Tabetic arthropathies of the spine are not extremely rare. Syringomyelitic arthropathies are much rarer. These spines need local support as well as general treatment. Operative fusion of the loose and unstable spines may be considered.

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CHAPTER IX

CHRONIC ARTHRITIS OF THE SPINE

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- VI. Comment to Chapter IX: Chronic Arthritis of the Spine

I. DEFINITION AND CLASSIFICATION

In view of the great confusion which exists regarding the identification of different types of chronic arthritis of the spine from the etiologic point of view, it appears best to follow the pathologic lines of division and to adhere to the recognition of the two great types of chronic arthritis: the rheumatoid or infectious, and the osteoarthritic or the degenerative type.[9, 10, 11] Goldthwait[17, 18] believes that the rheumatoid type may still be subdivided into a specific infectious type and in an atrophic type, but most of the observers content themselves with adherence to the two great pathologic types of osteoarthritis mentioned above, that is, the rheumatoid and atrophic on one hand, and the hypertrophic or degenerative on the other.

This classification into two main groups represents a well-defined pathologic division, but each of the main groups of arthritis, so far as the vertebral column is involved, may be further subdivided (Jones[21] and Lovett):

From the atrophic main group:

1. The spondylarthritis deformans as a part of the general arthritis of the atrophic or rheumatoid type. Here belongs also the so-called ankylosing spondylarthritis.
2. The Strümpell-Marie syndrome of spondylarthritis, generally considered an atrophic type, with peculiar typical distribution and development.

From the hypertrophic main group:

3. The Bechterew Type. This is a localized descending hypertrophic type of spondylarthritis which includes the so-called kyphosis senilis.
4. The general hypertrophic type of spondylarthritis of the spine as part of a generalized hypertrophic osteoarthritis.

II. ETIOLOGY

The etiology of arthritis of the spine does not differ materially from that of other joints. According to most authors the atrophic or proliferative type is infectious or toxic-infectious in character, while the hypertrophic type is considered to be metabolic (Painter[30]). The prevalence of this metabolic or hypertrophic type during adult or middle age is significant, since at this time the body activities relax, the habits become more sedentary, superfluous weight is taken on, and the food taken into the body is not utilized as it is during the earlier active years of life.

In the atrophic type the inflammatory element is in the foreground though it is not always possible to establish proof of a focus of infection.

Specific Etiologic Factors

1. Metabolic Factors

By some, faulty metabolism is considered as the principal cause of chronic arthritic conditions (Pemberton[31]). Pemberton found creatin and urea output unchanged in arthritis which seemed to him to dispose of the prejudice against protein as a causative factor. On the other hand, Magnuson[27] distinctly emphasizes the connection between high protein intake and joint pain, which is, in his opinion, evidence of the protein effect upon the joints. It has been long known to pediatricians that protein intolerance may exist in children and it is possible that it may be carried into adult life. In cases in which the x-ray and clinical findings showed typical hypertrophic arthritis of the spine, there was obtained (according to Magnuson) prompt recovery by withdrawal of all red meat and regulation of the bowels and general elimination. It seems that, from these observations, recovery from either the atrophic or hypertrophic type depends in many cases, not only upon the removal of actual infectious foci but also upon the proper management of the metabolic requirements of the body, especially adequate food assimilation.

Blood Chemistry.—Attention has been directed to a lower sugar tolerance in patients suffering from infectious arthritis (Warburton); but it is doubtful whether this has any pathognomonic significance; the writer, at least, has satisfied himself that lowered sugar tolerance exists also in other chronic conditions of bones and joints. Calcium and phosphorus, being the inorganic substances of special interest, were also investigated. Nachlass[29] was unable to verify the observations of earlier writers that abnormality of the calcium metabolism exists in arthritis deformans. There was, also, no difference found in the blood analysis between rheumatoid arthritis and the hypertrophic type. The only difference noted is the tendency of the phosphorus readings to be lower in the osteoarthritic than in the rheumatoid group.

On the other hand, there are other observers (Weill[44] and Guillaumin), who find a definite increase in calcium in chronic ankylosing rheumatism. But, even according to these investigations the hypercalcemia is not a constant factor and blood calcium is not always increased. The calcium-phosphorus product is likewise not altered as regularly in arthritis as it is in other conditions, for instance, in fractures or in rickets, where a reduction of this product is the rule.

2. Focal Infections

Focal infections of the upper respiratory tract, the gall bladder, the genito-urinary system, must be conceded a similar etiologic importance for arthritis of the spine as they have in the generalized type of arthritis. Their significance becomes decidedly less, however, in later years, with the possible exception of the teeth, the gall bladder, and the prostate, which retain important relations to chronic arthritis of the spine. Sometimes undue radicalism is used in the removal of infectious foci. This pertains particularly to the wholesale removal of teeth. If the present adequate methods of determining the infection around the teeth fail to give any evidence one should refrain from indiscriminate removal (Harned[19]).

In children and adolescents foci situated in the upper air passages frequently sustain arthritic conditions in the spine and the joints of the extremities (Gibney[16]). Tonsils retain their effect upon arthritis into the adult and later life, and one often sees rigidity and pain disappear after tonsillectomy (Schwartz[37]).

3. Body Mechanics; Intestinal Stasis

Faulty body mechanics and dynamics are often a factor in producing arthritis (Swaim[40]). Preiser[33] was one of the first to emphasize the connection between static strains and reactive arthritis of the joints. A great deal of attention is now being paid to the connection between intestinal infections and the atrophic and hypertrophic types of spondylarthritis.

This focus is often merely an added factor to faulty physiologic and biochemical conditions, so that its removal is not in itself sufficient to eradicate the disease. Recognition of the intestinal factor in arthritis, however, is a decided step in advance and Swaim and others believe firmly in the connection between intestinal stasis and putrefaction and arthritis. The patient with hypertrophic arthritis, with the heavy type of anatomic build and with a big large intestine, tends to flaccid constipation and incompetent iliocecal valve; his intestines are frequently distended, atonic, and he has a heavy, pendulous abdomen. On the other hand, the atrophic patient is usually of the slender anatomic type with short intestines which tend to spasticity.

Visceroptosis is common in either type. The chief effect of it consists in the production of an intestinal stasis, and a constant toxemia. This may be the case in spite of the fact that x-ray pictures in visceroptotics show apparently normal intestinal evacuation (Silver[39]).

Evidence has been introduced that during digestion of food toxic substances enter the blood stream, causing systemic disorders (Brown[6]). According to Adami[1] the normal invasion of bacteria from the intestinal tract is comparatively slight and the physiologic function of the cells brings about the destruction of the bacteria and prevents local and general reaction. Under certain conditions, however, the intestinal intake of bacteria becomes greatly increased and then the effect of continuous invasion of bacteria in considerable numbers leads to a stage of tissue exhaustion. In the joints and in the spine this exhaustion is a predisposing factor in the development of arthritis. A good deal of attention has been focused lately upon the intestinal flora of the large intestine. Ely[11] and others contend that the finding of Ameba histolytica is frequent in the stools of patients affected with arthritis. Kofoid and Sweezy,[23] in a case operated upon for arthritis deformans, found, in the head of the femur, Endameba dysenteriae embedded within the bone. On such grounds, the intestinal tract, especially the larger intestine, has been considered as a focus of infection. Judging from the influence of certain diets upon the intestinal stasis, and upon the production of visceroptosis, it is believed that foods that are rich in minerals are essential for the body balance, while those especially rich in carbohydrates are detrimental and predispose to arthritic changes in joints and spine.

From the earlier investigations of Preiser to the newer contributions of Brown, Swaim and others the appreciation of faulty body mechanics appears as a strong factor in atrophic arthritis. The importance of the low diaphragm, of the relaxed abdomen, of visceroptosis in general, is now uniformly acknowledged (see Chapter II, Visceroptosis).

III. THE ATROPHIC TYPES OF CHRONIC ARTHRITIS OF THE SPINE

1. Atrophic Type of Spondylarthritis: Chronic Ankylosing Arthritis

a. Etiology.—This type is prevailingly of infectious nature. Proof of this are the truly inflammatory changes seen in the joints, as well as the fact that in a part of the cases febrile polyarthritis precedes the chronic stage. In the light of the newer knowledge of focal infection, the condition can be ascribed to the more common localizations of primary foci, namely, those situated in the head, in the paranasal sinuses, as well as in the intestinal tract and in the organs of the pelvis. Especially the latter play a considerable part in the production of this disease.

b. Heredity.—That heredity is of importance remains doubtful. Incidences are given, however, where the tendency to arthritic conditions in the spine or other joints is traceable to families and relatives of the patient. It is more likely that it is a constitutional habitus predisposing to arthritis, rather than the disease itself which is being transmitted.

c. Trauma.—Geilinger[15] estimates that trauma appears as an etiologic factor in 14 per cent of all cases. Most authors concede that trauma is only a predisposing element, while the true cause is of infectious nature. It must be admitted, however, that the disease often becomes manifest after trauma.

Static forces are likewise of importance. If one joint is involved in a change of the normal static and dynamic relations, the neighboring joints are likewise affected, a fact which cannot fail to be of influence upon the progressive character of the disease, especially in the spine and the lower extremities. So we often find that one vertebral articulation after another becomes involved under the same static conditions (Kreuzfuchs[24]).

d. Incidence.—The male sex prevails, probably because more exposed to causative factors. The highest incidence is between the 3rd and 5th decade (Ruhe).

e. Pathologic Anatomy (Plate LXIX, 2).—Inasmuch as spondylarthritis atrophica of the spine is part of the general rheumatoid or atrophic arthritis, the pathologic changes in the intervertebral articulations vary in no essential detail from those seen in the larger articulations. There is the same general atrophy of the bone, the periarticular swelling and infiltration, the ligamentous thickening, and the secondary atrophy of the cartilage coverings of the articulations.

A very characteristic feature seen in a large number of cases belonging to the atrophic type is involvement of the ligamentous structures. They often engage in a process of secondary ossification, and, for this reason, the name of syndesmitis ossificans (Simon[38]), or spondylitis ankyloarthritica (Fraenkel[13]), is applied to this condition. This feature of ligamentous ossification is shared by the Strümpell-Marie type of spondylarthritis which will be discussed later.

The bodies of the vertebrae themselves do not present any essential change in form, and not only the vertebral bodies but also the intervertebral spaces appear preserved. By virtue of the ligamentous ossification process the spine becomes partially or totally stiff. The ossification involves mainly the anterior longitudinal ligament which often forms a uniform band over the anterior aspect of the vertebral bodies. Next to this it is the ligamenta flava, the capsular ligaments, the costovertebral ligaments, and the supra- and infraspinous ligaments which succumb to ossification (Valtancoli,[43] Leri[25, 26]). One often sees stalactitic formations of bone spicules within the texture of the ligamenta flava uniting the neighboring laminae.

PLATE LXIX

Fig. 1.—Upper left. Hypertrophic cervical arthritis involving one articular facet and lamina.
Lower left. Normal cervical vertebra.

Right. Hypertrophic cervical arthritis involving body of cervical spine.

Fig. 2.—Atrophic arthritis of cervical spine (note compression of bodies).

Fig. 3.—Hypertrophic arthritis. Calcification of intervertebral and costovertebral ligaments.

Fig. 4.—Hypertrophic arthritis. Kyphotic section of spine. (Calcification of ligaments.)

Fig. 5.—Hypertrophic arthritis. Obliteration of sacroiliac joint. Fusion of 5th lumbar to the sacrum.

Fig. 6.—Hypertrophic arthritis. Fusion of 5th lumbar to sacrum. (Numerous exostoses.)

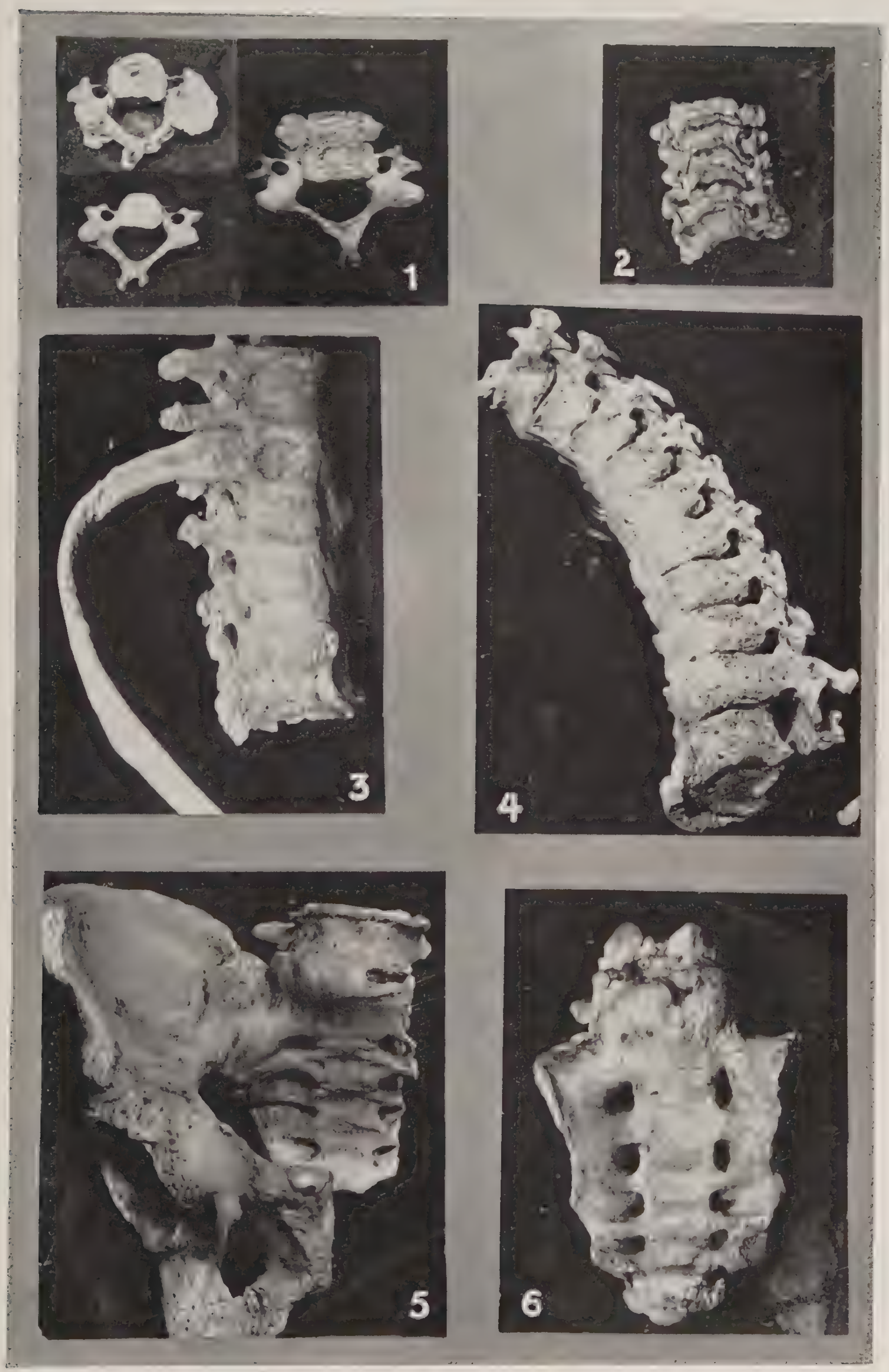

PLATE LXIX

The most significant feature of spondylitis ankylo-poetica lies in the changes of the intervertebral joints. The joint fissures become indistinct and the entire articular process appears washed out and mottled until finally the intervertebral articulations become solid masses. Likewise the costovertebral articulations show irregular contours and often synostosis. In contrast to ligaments and articulations, the vertebral body remains unchanged and shows no signs of spur formation or exostosis. In this, they differ strikingly from the hypertrophic type of arthritis.

f. X-ray Findings.—The x-ray picture shows the unchanged contours of the vertebral bodies and there is no change in the intervertebral spaces, the latter being well outlined. For this reason superficial investigation of the x-ray picture may fail to reveal any pathologic changes; but, when one examines the outlines of the intervertebral articulations, one often finds them definitely altered, blurred, and the joint fissures no longer visible. The bodies of the vertebrae, although clearly outlined, appear united by fine shadows which represent the process of ligamentous ossification. This can be seen especially well in ankylosing types, the so-called spondylose rhizomelique of Pierre Marie. These shadows appear much lighter than the shadows of bone and they correspond in shape and direction to the ligamentous apparatus.

g. The Symptoms.—

(1) *Onset.*—The onset of atrophic spondylarthritis is insidious. It progresses slowly and steadily until a state of total rigidity is reached.

(2) *Pain.*—The most characteristic clinical symptom is back pain. This pain becomes aggravated by exertion and lifting, bending over, and it does not entirely disappear with rest. This is important as it differentiates this condition against traumatic disorders, especially of the lower back, which can usually be controlled by position or rest (see Chapter V).

Radiating pain is quite frequent; it also may be elicited and aggravated by exertion and strain, and is not entirely controlled by rest. It is the arthritic change in intervertebral articulations and foramina which is productive of radiating radicular symptoms. They have a typical anatomic distribution along the intercostal nerves. Certain postures and attitudes which may have something to do with the narrowing of the intervertebral foramina, such as backward extension or inclination toward the diseased side, elicit or increase the symptoms of radiation. The back muscles in the affected region are strongly contracted leading to contractural attitudes. Radiating paroxysmal pain in the cervical spine is especially frequent, sometimes combined with complete ankylosis (Roger and Astier[36]); and sometimes it is associated with arthritic torticollis (Forrestier[14]). Brachial neuralgia and sciatica are not uncommon radicular symptoms. Radiating pain in the lumbosacral region with distribution along the thighs and legs is frequently seen in lumbosacral arthritis.

Epstein[12] reports six cases of arthritis of the lumbar spine involving the intervertebral articulations and perivertebral tissues with pain referred to the sacroiliac region. Hyperesthesias, paresthesias of the arm, girdle pain, as well as the intercostal pain and the radiations of the lumbosacral plexus already mentioned, are often complained of. One notes hypersensibility of the skin, atrophy of the muscles of shoulders and back or hip. Frequently the temporomandibular joint becomes included in the arthritic ankylosing process; involvement of the sternoclavicular articulations is uncommon.

An early symptom which is due to the involvement of the costovertebral articulations is the respiratory pain. Movement in these articulations causes radiating pain along the ribs. The thorax goes into a more expiratory position and the ribs assume a greater downward slant, so that the intercostal spaces are narrowed. The fixation of the rib is first due to muscular spasm and later becomes ankylotic and permanent. Costal breathing, being painful, becomes more and more supplanted by abdominal breathing. The result is a certain respiratory embarrassment upon exertion; the patients easily complain of shortness of breath. In some cases one finds the small costovertebral joints alone affected, so that respiratory embarrassment may appear as an early and outstanding symptom (Proebster[34]).

3. *Deformity (LXX, 3).*—The spine appears deformed in shape of an arcuar kyphosis in the dorsal section. The lordosis of the lumbar spine becomes effaced and the body in its upper portion is thrust forward. A deep furrow is seen running horizontally across the abdominal wall at the level of the umbilicus. Due to the involvement of the lumbar spine and the sacrolumbar junction, the pelvic inclination becomes greatly diminished, so that the thighs go into extension and this, together with the forward thrust of the head and neck, produces a typical posture. There are, however, some exceptions to this typical attitude. Some cases assume the flat back type instead of a kyphosis, and lateral deformities of the spine, also, are occasionally observed.

h. Differential Diagnosis.—From the viewpoint of differential diagnosis tuberculous spondylitis and hypertrophic arthritis are the two principal conditions to be considered. Others are gonorrheal arthritis, lues, tumors of the spine, and arthropathies.

1. *Tuberculous arthritis* is characterized by its limited extent and the prevalence of bone destruction over bone reaction and bone repair.

2. *Against hypertrophic arthritis* speaks the fact that the contours of the bodies, aside from the general bone atrophy, are usually well preserved in atrophic spondylitis and there is no formation of spurs or bony bridges as seen in osteoarthritis of the spine.

3. *Luetic inflammation* of the spine is recognized by the intermittent, and especially nocturnal pain of boring type, by the history and the positive Wassermann reaction.

4. *Gonorrheal spondylarthritis,* on the other hand, shows no characteristic features which differentiate it from ankylosing arthritis of the chronic infectious type. Here, one must rely wholly upon the history and the onset of the disease.

5. *Tumors* of the spine, however, especially primary myeloma or metastatic carcinoma, do not offer very great difficulty to the differential diagnosis, except in very early stages. These malignancies produce considerable pain and reflex contracture of the muscles, and their x-ray picture is more or less suggestive; destruction is rapid and extensive. The pain is intense and uncontrollable. There is more difficulty in differentiation against leucemia and Hodgkin's disease, but in these conditions also the examination of the blood, and the finding of primary tumor in the x-ray picture, and the general condition of the patient are of significance.

6. In the *tabetic arthropathies* the deformation of the spine, the shape of the kyphosis, the frequent combination with scoliotic deformities are significant. Most characteristic, however, for tabetic arthropathies is, in contrast to the atrophic type of arthritis, the enormous proliferation of bone and ossification of ligaments, the lack of restriction of the mobility, and the absence of pain. Aside from this, general tabetic signs such as absence of reflexes, irregularity of pupils, ataxia, the Wassermann reaction, are usually present to substantiate the diagnosis.

2. The Strümpell[41]-Marie[28] Type of Ankylosing Spondylarthritis (Plate LXX, 1)

a. Etiology.—Aside from toxic infective agencies which assume the same significance in this form of spondylarthritis as they do in the atrophic type, trauma must be considered as a factor, according to Fraenkel[13] and Knaggs[22] who expressly call attention to this point. Cases of ascending ankylosing spondylitis starting with inflammation of the hip joint are reported as produced by occupational strain such as sitting on a high chair, or by carrying a heavy load. One must also include postural strains as etiologic factors. Visceroptosis, intestinal stasis, or malpostures, faulty body balance in general, undoubtedly exert the same predisposing influence upon this type of arthritis which they exercise in the atrophic ankylosing form.

b. Pathologic Anatomy.—The Strümpell-Marie type of ankylosing spondylitis is an ascending type of atrophic arthritis which involves the lower portion of the spine and also some of the larger articulations of the body. It is also known as spondylose rhizomelique, and is remarkable for a gradual ossification of the spinous and intraarticular ligaments, and for the frequent fusion between the intervertebral articulations. The most peculiar feature of this type is the rapidly developing kyphosis due to spondylitic changes in the lower lumbar and middorsal spine and the associated involvement of a number of the larger joints. This differentiates this condition from the Bechterew type (to be described later). In the latter the upper portion of the spine is involved first; the pathologic process is of descending character, and it only exceptionally includes the large joints of the body.

Because the ossification of the spinal ligaments is a characteristic point in Strümpell-Marie's type, it is also called spondylitis ossificans ligamentosa

(Knaggs[22]). With the ossification in the ligaments there is associated an extensive atrophy and rarefaction of the vertebral bodies. The ankylosis, mostly ligamentous and intraarticular, is to be considered as a curative phenomenon, since it limits the deformity. The large joints which participate in the ankylosing spondylarthritis of Strümpell-Marie type, are the hips, the shoulders, the knees, and the sternoclavicular articulation. It begins as a coxofemoral and sacrococcygeal form, which may be followed later by a humeroscapular period, in which the joints of the shoulder girdle become included. The anterior longitudinal ligament ossifies especially in the cervical and lumbar regions, that is, over the convexities of the spinal curves. This ossification obviously shares with the ankylosis of the intervertebral articulations the function of limiting the deformation caused by the disease.

Hutchinson[20] gives a classic description of the ossification of the anterior longitudinal ligament, a rather irregular, not very well defined structure. The ossification of this ligament is seen in early stage of the disease. The posterior common ligament and the ligamenta flava, the ligaments of the articular processes, i.e., the capsular ligaments and the costovertebral ligaments become involved in the ossification process later.

c. **The Clinical Symptoms (Plate LXX, 1)**.—The period of most frequent occurrence is the age between thirty and forty. In Valtancoli's[43] series most of the cases observed were between thirty and thirty-five years of age.

1. *Immobility: Rigidity.*—The extensive stiffening of the spine due to ankylosis of intervertebral and costovertebral articulations and ligamentous ossifications, is the principal clinical feature of the disease. Ankylosis of the larger articulations, especially of the hips, completes the picture of rigidity. The smaller articulations, such as those of the fingers, do not become ankylosed, but may become painful.

2. *Pain.*—Pain is a prominent symptom which varies greatly in intensity and localization. Saccrococcygeal and ascending pain is observed early. The difficulty to distinguish at this stage between spondylose rhizomelique and the ordinary ankylosing type of arthritis is considerable; the disease will often begin in the iliofemoral articulations and remain there for a considerable length of time before it gradually ascends in the spine.

3. *Deformity (Plate LXX, 1).*—The deformity caused by the pathologic changes is an arcuar kyphosis in the dorsolumbar region.

When ankylosis of the spine is complete, the thorax offers a particular aspect: it is flat, strongly inclined, appears entirely immobile, and does not participate in the respiratory movement, so that respiration becomes exclusively abdominal. The kyphotic deformity of the spine may attain very extensive degrees. The patient is constrained to maintain himself in balance with a high degree of forward flexion. The body is then thrown forward, hips and knees are flexed, and the gait becomes very laborious. Strümpell and Marie described cases of progressive arthritis which ended up in complete

PLATE LXX

Fig. 1.—Strümpell-Marie type of ankylosing arthritis of the spine and hips.

Fig. 2.—Bechterew type of hypertrophic arthritis of the spine.

Fig. 3.—Atrophic arthritis. Generalized.

Fig. 4.—Hypertrophic arthritis. (Note bridging of lumbar spine.)

Fig. 5.—Hypertrophic arthritis of cervical spine.

Fig. 6.—Hypertrophic arthritis. Extensive bridging of lumbar spine.

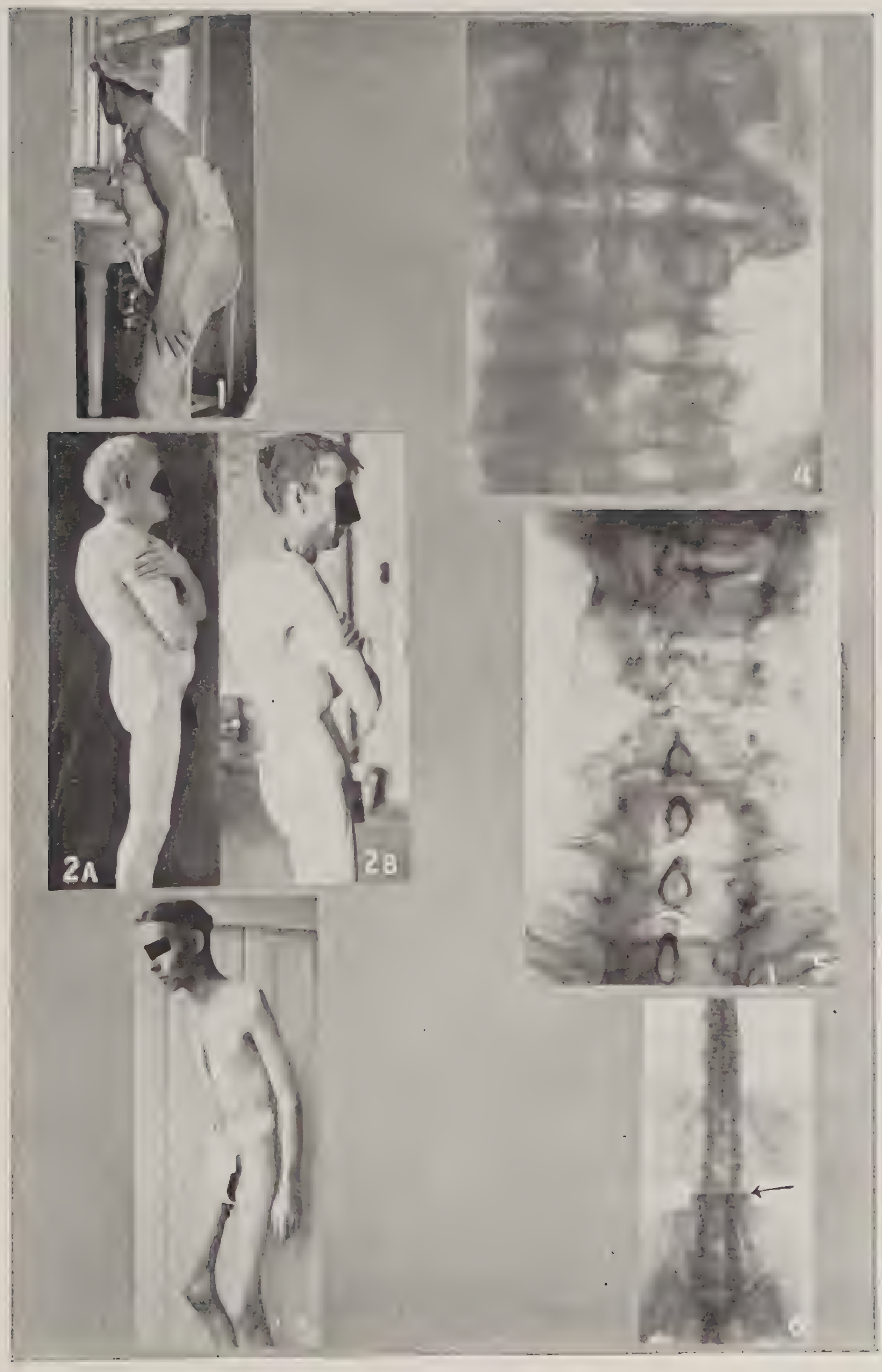

PLATE LXX

ankylosis of the spine and hips, so that the head, trunk, and femur were firmly flexed to one another and became completely rigid, whereas the other joints showed normal mobility.

IV. THE HYPERTROPHIC TYPES OF CHRONIC ARTHRITIS OF THE SPINE (PLATE LXX, 2)

1. The Bechterew Type

a. Definition and Description.—This type belongs to the second great group, namely, the hypertrophic group of arthritis deformans. It was first described by Bechterew[2, 3, 4] in 1892 on the basis of five hundred observations of ankylosis of the spine associated with kyphosis. The symptoms observed by him were immobility of the spine, absence of pain or tenderness, accompanied by atrophic and paralytic conditions of the muscles, kyphosis, and a decrease in sensibility of the lower cervical, dorsal, and occasionally, also, of the lumbar cutaneous nerves. In some cases he also found symptoms of motor irritation, such as twitching and contractures. He found this disease usually limited to the upper portion of the spine, while the joints of the extremities were not involved. Mild degrees of this condition were seen in the humpback spine of older people: kyphosis senilis.

This disease may start in early life and remain stationary, to become aggravated again in later years, and there is a possible connection between this condition and osteochondritis deformans juvenilis (see Chapter II). Because of the paresis of the back muscles, Bechterew's type is also known as spondylitis muscularis.

b. Etiology.—In this type of ankylosing arthritis we do not find a direct association with infectious foci. It is more likely that metabolic toxins are at work. Besides this, other etiologic factors are to be considered, among which trauma and heredity seem to be of considerable importance; in view of this influence of heredity and trauma, the disease is also known as kyphose heredotraumatique.

Faulty posture, long occupational strain, debilitating diseases, occurring in early youth and adolescence, may also predispose to this type of spondylarthritis.

Attention is further called to the effect of dysfunction of the thyroid gland, and to the cessation of the ovarian function (Cohn-Wolpe[8]). In some cases pigmentation and asthenia suggest disease or involvement of the suprarenals. The association of scleroderma with this type of arthritis likewise points to a connection with the glands of internal secretion.

c. Pathologic Anatomy.—In fully developed cases the spine becomes absolutely immobile and the bodies of the vertebrae are fused anteriorly. The discs are either atrophic or disappear completely. This is an important point of differentiation against the ankylosing type of Strümpell-Marie in which the intervertebral discs are not atrophic and do not disappear. With the disappearance of the disc the adjacent portions of the vertebrae are brought in contact and fuse, sometimes with slight lateral deviation.

The secondary changes consist in alterations in the shape of the body. In the senile type atrophy of the discs extends throughout the spine. In contrast to the spondylitis ossificans ligamentosa of Strümpell-Marie, we find in Bechterew's type characteristic chondroarthritic spicules at the margins of the vertebral bodies, which are prone to impinge upon one another and gradually lead to fusion. In the large collection of osteoarthritic specimens of the spine of the Warren museum, it was found that the intervertebral foramina were peculiarly free from osseous changes, although chondroosseous ridges may impinge upon the nerves after their exit from the intervertebral foramen. In contrast, also, to Strümpell-Marie's type, the various vertebral ligaments are not ossified. The spondylitis muscularis is a variation of the Bechterew type. Here, one finds weakness and atrophy of the muscles associated with a thinning and disappearance of the intervertebral discs and with marked dorsal kyphosis. A thick layer of bone is often found spread over the anterior surface of the vertebra, but there is no sign of ossification of the vertebral ligaments.

The Nervous System.—The examination shows hyperemia of the cranial and spinal dura. The cervical dura especially is thickened and the spinal ganglia have been found suffused. Microscopically, Bechterew found the posterior roots degenerated throughout, while the anterior showed a less extensive fibrous degeneration. In his cases there was also evidence of cord degeneration, especially in the upper dorsal and lower cervical regions. The cord degeneration involved the columns of Goll and Burdach. The gray matter of the cord shows no changes, but in the root ganglion many degenerated cells are found and leucocytic infiltration. On the strength of these pathologic findings, Bechterew suggested that the degeneration of the posterior roots could be explained by a chronic inflammatory process of the meninges, resulting in compression of the roots at their point of anchorage to the cord, and furthermore in adhesions of the spinal ganglion to the dura. According to him the subdural and meningeal changes are the primary condition, while the degeneration of the spinal nerves is secondary. Goldthwaite[17, 18] believes that the root symptoms are due to pressure from inflammatory swelling at the vertebral foramina.

Combinations.—Although in Bechterew's type the disease is usually confined to the spine, particularly the cervical and upper dorsal sections, extending gradually downward, involvement of other joints is occasionally noticed. Simon[38] mentions a case in which the temporomaxillary joint was involved, leading to complete ankylosis; and Brennsohn[5] describes a combination of the Bechterew with the Strümpell-Marie type, namely, a curvature of the upper portion of the spine with involvement of the hip and associated with atrophy of the limbs, increased reflexes, inequality of the pupils.

d. Clinical Symptoms.—The cardinal symptoms are: (1) immobility or incomplete mobility of the spine; (2) the gradually developing deformity with posterior convexity which causes the upper dorsal spine and the head to be strongly thrust forward; (3) a weak or paretic condition of the muscles of the body, of the neck, of the extremities, with atrophy of the muscles of the shoulder girdle; (4) a diminution of the sensibility, especially in the region of the cutaneous branches of the dorsal and lower cervical nerves.

(1) The *immobility* or incomplete mobility of the spine.

The gradual onset of the disease and the slow progress naturally produce ankylosis with restriction of motion in all shades and degrees. Involvement of the cervical spine alone has been observed as an early stage of the disease (Tremoliere and Colombier[42]). In the x-ray picture the cervical vertebrae were apparently welded to each other with hook-shaped osteophytic proliferations, while the dorsal and lumbar spine appeared normal.

(2) *Deformity.*—The deformity with posterior convexity causes various changes in the posture and attitude of the body. In extreme cases the head is thrust straight forward or even downward so that the patient has great difficulty in looking up.

(3) *Weakness of the Muscles of the Body.*—In some instances the weakness of the muscles of the body is so pronounced as to constitute the outstanding clinical picture (spondylitis muscularis). In other cases the involvement of the muscles of the shoulder girdle is especially noticeable. No true paralytic condition of the muscles is seen and it is a question whether the muscle weakness is not one of disuse, secondary to the rigidity of the spine and the great difficulties in locomotion.

(4) *Disturbances of Sensibility.*—These are noted especially in the region of the cutaneous branches of the lower cervical and dorsal spine. Root pains are not uncommon and very often follow the run of the greater occipital nerve and the cutaneous branches of the brachial plexus.

Occasional symptoms are paresthesias, local hyperesthesias, pain in the back, in the region of the neck, or in the extremities. To this must be added also the arrest of the respiratory activity of the thorax, which leads to an exclusively abdominal type of breathing similarly as in the atrophic type of Strümpell-Marie.

2. The Spondylitis Deformans of the Spine (Hypertrophic Arthritis, Osteoarthritis of the Spine, Arthritis Deformans)

a. Definition.—This second great type of chronic arthritis of the spine as part of a general involvement is characterized by changes in the vertebrae which are essentially marked at the vertebral borders and near the articular bodies of the joints. The changes consist in more or less distinct deformation of the bodies of the vertebrae and in the production of marginal osteophytic growths. These sometimes lead to bridges across the intervertebral discs, so that a number of vertebrae become united into a solid block. However, complete osseous ankylosis is not the rule in this type of arthritis. The bodies usually do not fuse nor do the vertebral articular processes, or the costovertebral articulations. It is more an interlocking due to the irregular osteophytic outgrowth. If a fusion occurs it is entirely due to a melting together of these osteophytic lips or spurs and there is always to be seen a line of demarcation which denotes the contours of the vertebral bodies. It is remarkable that at the same time the bodies themselves succumb to an osteoporosis and flatten in vertical direction, while their transverse diameter becomes increased. The result of this flattening is an accentuation of the normal physiologic curves of the spine.

The changes, however, are not limited to the bodies of the vertebrae; the intervertebral articulations take part in similar pathologic formations and so do also the pedicles. The ultimate deformation of the vertebral body is not a primary phenomenon but it is subsequent to primary alterations of the discs which become inelastic, flattened and protruding.

Spondylitis deformans of the spine involves almost always male individuals around the fiftieth year of life, while the Strümpell-Marie and Bechterew types of ankylosing spondylitis usually involve younger persons.

b. Etiology.—

(1) *The Age Factor in Hypertrophic Arthritis.*—It has been pointed out by Willis[45] that, since bone lipping and bone hypertrophy are the most important pathologic changes in hypertrophic arthritis, and since on the other hand, these changes are also seen as physiologic symptoms of senescence, there is great difficulty in placing the right value upon these phenomena as they present themselves in the x-ray picture, or upon the dissecting table. One must have knowledge of the force of incidence of bone hypertrophy as a sign of physiologic age. Willis made a study of the age as a factor in the production of normal hypertrophic changes by examining a series of six hundred and twenty-five spinal columns, limiting himself to such changes as appeared in the lumbar portion of the spine. He found that, aside from age, static and mechanical factors also have a hand in the production of these physiologic changes. Dividing his material into the three physiologic types as described by Goldthwaite, Painter, Osgood, and others, namely, in the slender, the average, and the heavy anatomic types, Willis found that the marked hypertrophic changes also were associated with vertical flatness of the spine, especially of the lower dorsal and lumbar sections where static and gravital stresses are most intense. If one establishes a relation between the height and width of the vertebrae as the vertical index of the body, it is found that in the slender type this ratio amounts to 69.5 per cent, in the average type to 63 per cent, and in the heavy type to 59.8 per cent, indicating the greater vertical compression which exists in the heavy type. Willis found that normally before the age of thirty-five practically no lipping existed. Between the ages of thirty-five and forty there appeared different degrees of changes, and these changes were greatest in the heavy type and least marked in the slender type. At the age of forty-five only 10 per cent of the slender type showed hypertrophic changes, and 83 per cent of the heavy type. At

the age of fifty all cases of the heavy type showed hypertrophic changes, at the age of fifty-five, all the cases of the average type, and at the age of sixty all cases of the slender type. This would indicate that the hypertrophic bone changes as seen as a physiologic sign of senility are much more general than is usually assumed, that they are definitely related to age, and that disease, therefore, cannot be the only determining factor. It must put us on our guard not to place too much significance upon hypertrophic bone changes of milder nature which appear in more advanced ages after forty-five or fifty, especially in persons of the so-called heavy anatomic build. It must be assumed that the bone and joint structures of the spine are subject to traumatic as well as to inflammatory irritation and that, therefore, greater responses to traumatic influences are seen in types which sustain gravital stresses to a greater degree. All this illustrates the difficulty of determining whether a certain grade of lipping shown in the roentgenogram is pathologic or still belongs to the normal physiologic changes.

(2) *Static Stresses.*—Many years ago Preiser[33] expressed the view that the hypertrophic changes of the spine represent a normal bone reaction to the wear and tear imposed upon the skeleton by gravital and other stresses. It now appears that certain responses to wear and tear become more pronounced in certain types by virtue of their individual anatomic constitution. So we see that hypertrophic bone changes in the x-ray do not necessarily mean inflammatory conditions, but often mean nothing but a greater or less degree of hypertrophic bone reaction. It follows that great precaution must be used in the interpretation of certain changes, both qualitatively and quantitatively, and it explains why so many spines with very pronounced proliferative bone changes represent comparatively few or no clinical symptoms.

c. Pathologic Anatomy (Plate LXIX, 1, 3, 4, 5, 6).—The pathologic changes in chronic hypertrophic arthritis of the spine may be divided in three groups (Wullstein[46]): (1) the changes at the edges of the vertebral bodies; (2) the changes in the intervertebral articulations; and (3) the changes in the intervertebral discs.

(1) Changes at the edges of the vertebral bodies as seen in the x-ray picture appear as marked marginal lippings, exostoses, which overgrow the intervertebral discs forming more or less extensive bridges of bone from body to body, and finally leading to ankylosis between the bodies.

(2) The intervertebral joints, and often the joints of the costovertebral articulations also become involved in the arthritic changes. This manifests itself in a thinning and a final disappearance of the cartilage and in hypertrophic changes around the articular bodies, resulting in impairment of the mobility of the joints. This finally ends in ankylosis both in the intervertebral and costovertebral articulations. The hypertrophic changes encroach also upon the lumen of the intervertebral foramina and thereby cause pressure symptoms upon nerves, especially in the cervical spine.

(3) Intervertebral Discs.—With the development of these marginal lippings and bone bridges, and with the attending immobilization of the vertebral bodies, the function of the intervertebral discs is eliminated and these structures become atrophic and finally disappear. According to some the pathologic process begins with degeneration of the intervertebral discs which lose their elasticity and become disintegrated. The disintegration of the intervertebral discs and the formation of marginal osteophytes is followed by eburnation of the bodies. According to Knaggs[22] this eburnation is found more prominently in the atlanto-occipital joint in which motion normally is most free. True fusion of the bodies or of the articular processes is unusual, the result is more an interlocking. Ankylosis between rib and vertebra is more likely to occur.

d. X-ray Evidence (Plate LXX, 4, 5, 6).—In the x-ray picture there is seen the characteristic flattening of the vertebral bodies showing at their margins osteophytic growths and spurs, leaf-like in shape. In the lateral view one distinctly sees these projections as they arise from the anterior corners of the vertebral bodies. More abundant proliferation may cover the surfaces of the bodies and form bridges uniting them apparently body to body. One also notes in the x-ray picture what appears to be an ankylosis of the small joints due to the same marginal proliferation. It is possible to recognize comparatively early stages of the disease. In cases which involve the intervertebral foramina the radiogram will also show projections of bone into these, and especially so in the cervical section. These projections narrow the lumen and explain the often very intense referred pain which accompanies osteoarthritis of the cervical spine. The disappearance of the intervertebral disc makes itself known by the narrowing of the free space between the bodies of the vertebrae; the latter appear broad, drawn out in transverse diameter, whereas they are flattened in the vertical direction. It is rarely that one finds the osteoarthritic changes spread over the entire spine; as a rule, only a section of the spine is involved.

e. Clinical Symptoms.—The four cardinal symptoms of osteoarthritis of the spine are: (1) the lameness and the pain in the back; (2) the decrease of the mobility; (3) the deformity; and (4) the referred and radiating pains.

(1) The first sign noted is usually a lame back. It becomes uncomfortable for the patient to bend the spine in performance of certain duties. According to the type of arthritis the pain is more definitely localized in the lower or the upper portions of the back. It is slow and insidious in development and it is decidedly progressive. The pain is sometimes brought about by sudden movement and it may last for a few days only and finally disappear. It is characteristic for this pain that it is usually worse in the morning and wears off somewhat during the day. Pain is furthermore aggravated by concussion and jarring, such as automobile riding or horse-back riding, by lifting, or any other kind of exertion; in more acute cases even by sneezing and coughing.

(2) *Restriction of Motion.*—With the appearance of pain and soreness there is seen an increased stiffness of the spine and because pain is elicited by motion a certain voluntary attitude of relief is observed. Frequently motion is restricted involuntarily also by reflex muscle contracture. As the pain, so also the rigidity of the spine is usually worse in the morning and subsides to a certain degree during the day. The disease goes on from the state of rigid contracture to that of ankylosis and with the latter the pain in the spine grows less and finally disappears entirely.

Rigidity of the costovertebral articulations produces a decrease of the respiratory capacity, and in many instances this decrease of the respiratory index is one of the earliest signs of the spine being involved in the osteoarthritic process. The respiratory impairment manifests itself by a flatness of the chest, the maintenance of a low respiratory position, and by the effacement of the lumbar lordosis. Further flexion of the trunk is generally executed with the aid of the hip joint. Hyperextension is also lost. Especially noticeable is the loss of the lateral mobility. Such a spine is eminently susceptible to strains and stresses (Ledderhose).

If the cervical spine is primarily affected, all motion, especially in the lower cervical spine, is encroached upon while the atlanto-occipital motion usually remains free to a remarkable degree. In the diseases of the dorsal spine the rotation of the body against the pelvis suffers the most and the patient's attitude in turning around becomes very guarded. Again, with the involvement of the lumbar spine the for- and backward bending as well as lateral bending of the trunk become greatly restricted.

(3) *Deformity.*—The usual deformity of the spine resulting from spondylarthritis is that of a dorsolumbar convexity or the ''poker-back'' curve, causing the head and neck to be thrust strongly forward and with it the upper part of the trunk. The patient has a peculiar gait; he often swings the hips in walking in order to compensate for the lack of rotation in the spine. In cases in which the hips are also involved, they usually become ankylosed in slight flexion and outward rotation, so that the patient is able to walk only with great difficulty. He shuffles along with the knees flexed and his ankles in abduction and outward rotation.

The involvement of other joints. The joints most frequently involved are the hip joints. The knuckles of the fingers usually show the characteristic changes of hypertrophic arthritis. Next frequently affected are the knees. The joints of the upper extremities as a whole remain free more often than those of the lower.

(4) *Radiating Pain.*—Radiating pain is not unusual in the hypertrophic type of spondylitis. In cervical spondylarthritis the radiation follows the distribution of the cervical nerves, especially the greater occipital nerve, to the occiput and back of the head. In dorsal disease the radiation most frequently follows the intercostal route. In lumbar spondylarthritis there is radiation into the buttocks, the thighs, legs, and feet.

Sometimes paresthesias precede neuralgic pain; or motor disturbances, as twitching, weakness, are seen as forerunners of sensory root symptoms.

For the clinical interpretation of this type of pain the finding of osteophytic changes at the intervertebral foramina or elsewhere in the neighborhood of the nerve roots is of importance.

f. Differential Diagnosis.—

(1) *Tuberculosis of the Spine.*—In tuberculosis the lesion is strictly localized, kyphosis is present in early stages, especially in children. Muscle spasm is frequent, covering a limited region of the spine. The x-ray shows bone destruction and often spindle-shape or round abscesses. On the other hand, in spondylarthritis the lesion is more diffuse, spasm is less pronounced, pain more of the radiating type, and the pressure tenderness and pain upon jarring are often absent. The x-ray picture shows bone proliferation and characteristic osteophytic formations.

(2) *Fracture of the Spine.*—Here, the history of trauma as well as the x-ray picture are determining factors. Deformity is usually present. Cord and peripheral nerve symptoms from compression are frequent. Attention must be paid to the fact that fracture of the spine is often associated with spondylarthritis and a dissociation of the two symptom complexes is necessary in order to evaluate properly the cause of the disability.

(3) *Ligamentous Strain.*—Here, the diagnosis at times becomes quite difficult. Strains are usually strictly localized and show the characteristic clinical signs which apply to strains in general (see Chapter V: Low Back Pain). One must remember, however, that arthritic spines in themselves are very susceptible to strains, due to the unequal and pathologic distribution of mobility, so that x-ray findings of osteoarthritic changes do not preclude strain. In a pure strain, in the x-ray evidence is negative.

(4) *Malignant Disease.*—In carcinoma or sarcoma there are usually the characteristic signs of bone destruction to be found in the x-ray picture. Clinically, malignancies are characterized by the early, intense, and usually uncontrollable pain, not depending upon mobility or rest. In myeloma, there is evidence of a primary tumor, the blood picture is often characteristic, and the urine often shows Bence-Jones bodies.

(5) *Paget's Disease.*—In Paget's disease the characteristic pathologic changes in the long bones and the changes of the skull are found. The general appearance of the patient as well as the insidious course are of importance.

(6) *Static Backache.*—This is a condition of great significance for the differential diagnosis. Static backache is often due to malposture. The purely localized pain, the absence of arthritic changes in the x-ray picture are deciding factors. In the symptomatic forms of low back pain (see Chapter V), caused by involvement of the prostate or the organs of the genitourinary apparatus, the primary affection of these organs can usually be established.

g. Prognosis.—The eradication of the underlying focus of infection is as important a point in osteoarthritis of the spine as it is in the atrophic form.

While in the atrophic type the infectious cause can very often be established by investigations of the upper air passages, the teeth, the intestinal or genitourinary tracts, in the osteoarthritic type the chances for relief from these measures are much less promising. Here, the causes are much more often of toxic nature, due to the disturbances of the gastrointestinal tract, or insufficiency of the iliocecal valve with ensuing stasis and visceroptosis. When these conditions are recognized and duly rectified, the outlook for the improvement and cure of the condition becomes considerably brighter. It must be remembered that malposture or visceroptosis gravely interferes with the digestion and gives rise to intestinal fermentation and to absorption of the products of putrefaction from the intestinal tract. In older people special attention must be paid to the function of the digestive apparatus. The prognosis as to the outcome is usually more favorable in the hypertrophic type than in the atrophic type. With the completion of the ankylosis the subjective symptoms gradually subside and the patient again becomes comfortable. It is usually the exacerbation of the trouble due to latent infection which causes the distressing retardations and delays the natural biologic conclusion of the process. Even the severest cases can be made comfortable by complete rest and complete ankylosis.

V. THE TREATMENT OF CHRONIC ARTHRITIS OF THE SPINE

On the whole, the principles of the treatment of chronic arthritis of the spine run parallel to those governing the treatment of arthritic deformities in general.

1. General Treatment

Removal of foci of infection from the upper respiratory tract, from the teeth, the intestinal or genitourinary tract, after thorough investigation, are necessary preliminaries. Attention must then be directed to faulty body mechanics, muscular wasting and circulatory deficiencies. This means correction of malposture or visceroptosis by muscle development and support (see Chapter II) so far as the state of pathologic changes in the spine will permit.

Recumbent or ambulatory, the patient must receive thorough care of the musculature of his body and extremities, a factor so often neglected in arthritic cases. All arthritic patients are eminently susceptible to fatigue. Massage, gentle, well-applied exercises are of great value, but one must always beware of overexertion.

The diet must be specially selected: rich in mineral, in cellulose and fats, moderate in proteins and poor in carbohydrates. Elimination is most important; flushings and high enemas should be given in preference to cathartics. Abdominal massage is an excellent means to stimulate intestinal activity.

2. Local Treatment

a. **Recumbency. (Plate LXXI, 1).**—In immobilization by bed-rest in earlier cases, the patient is placed on the frame until the painful stage is passed; then the back is sufficiently immobilized by supportive apparatus. Immobilization in recumbency should be carried out until all the muscle spasm has become relaxed and such correction has been effected as might be possible in consideration of the definitely established pathologic changes of the spine.

b. Ambulatory Treatment.—When the painful stage has passed, the ambulatory treatment is undertaken. Stabilization of the spine is accomplished by supportive apparatus. We do not favor the use of plaster of Paris casts except in those cases which show persistent tenderness and radiation, and where, as in old patients, it is essential that the patient relinquish the recumbent position as early as possible; or, in patients, who, for some reason or other, cannot be subjected to recumbent treatment.

For the ambulatory treatment a removable appliance is most suitable. Good body braces give better fixation to the spine than the plaster jacket and they allow, at the same time, more consideration for the comfort of the skin and for the development of the musculature. While it is true that in the arthritic spine the ultimate aim is ankylosis, there is, however, a long period of comparatively painful mobility of the spine to be gone through, and this entails a great deal of discomfort and suffering for the patient. A comfortable leather jacket or brace opens the possibility of not only sufficient support for the spine during the ambulatory hours of the day, but it also gives a chance to take care of the muscles of the back (see Chapter V).

The combination of brace treatment with massage, diathermy or application of heat in any form, gives especially satisfactory results. Massage, as a general therapeutic measure in arthritis, has been considered above. Applied to the musculature of the affected spine it greatly develops their tone, so that they become better qualified to maintain balance and posture. Daily sittings of fifteen to twenty minutes are advisable. Exercises can be given to the joints not involved in the arthritic process for their beneficial effect upon the general health; the spine itself is better let alone.

c. Correction.—In extreme flexion deformity correction may be obtained by placing the patient on a frame, curved to fit the back, in which the kyphotic deformity is gradually and gently straightened out by traction applied to head and pelvis. All this requires a great deal of bedside supervision. The patient should never be uncomfortable and the correction of the deformity must be accomplished very gradually and painlessly. It is obvious that such correction can only be successful and should only be attempted to the degree to which the contracted musculature can be made to relax. True ankylosis of the intervertebral articulations naturally forbids any attempt at correction. Forcible correction of the back has been attempted from time to time; this is a practice which is to be utterly condemned, since it is not only dangerous but also useless.

d. The Operative Treatment.—

(1) *Operative Fixation of the Spine.*—Operative fusion of the arthritic spine is not the routine treatment, and is applicable only to very exceptional cases. In some cases the ultimate ankylosis of the spine develops

PLATE LXXI

Fig. 1.—Hypertrophic arthritis involving spine (note support of head and shoulders during traction).

Fig. 2.—Arthritis involving articular facet. Acute symptoms.

Fig. 3.—Metastases of carcinoma of breast to 4th lumbar and 10th rib (osteoclastic).

Fig. 4.—Metastatic carcinoma. Destruction of body of 10th rib, 11th dorsal, 12th dorsal, and 1st lumbar (osteoclastic.)

Fig. 5.—Metastases of carcinoma of prostate to ileum, sacroiliac joint and head of femur (osteoclastic).

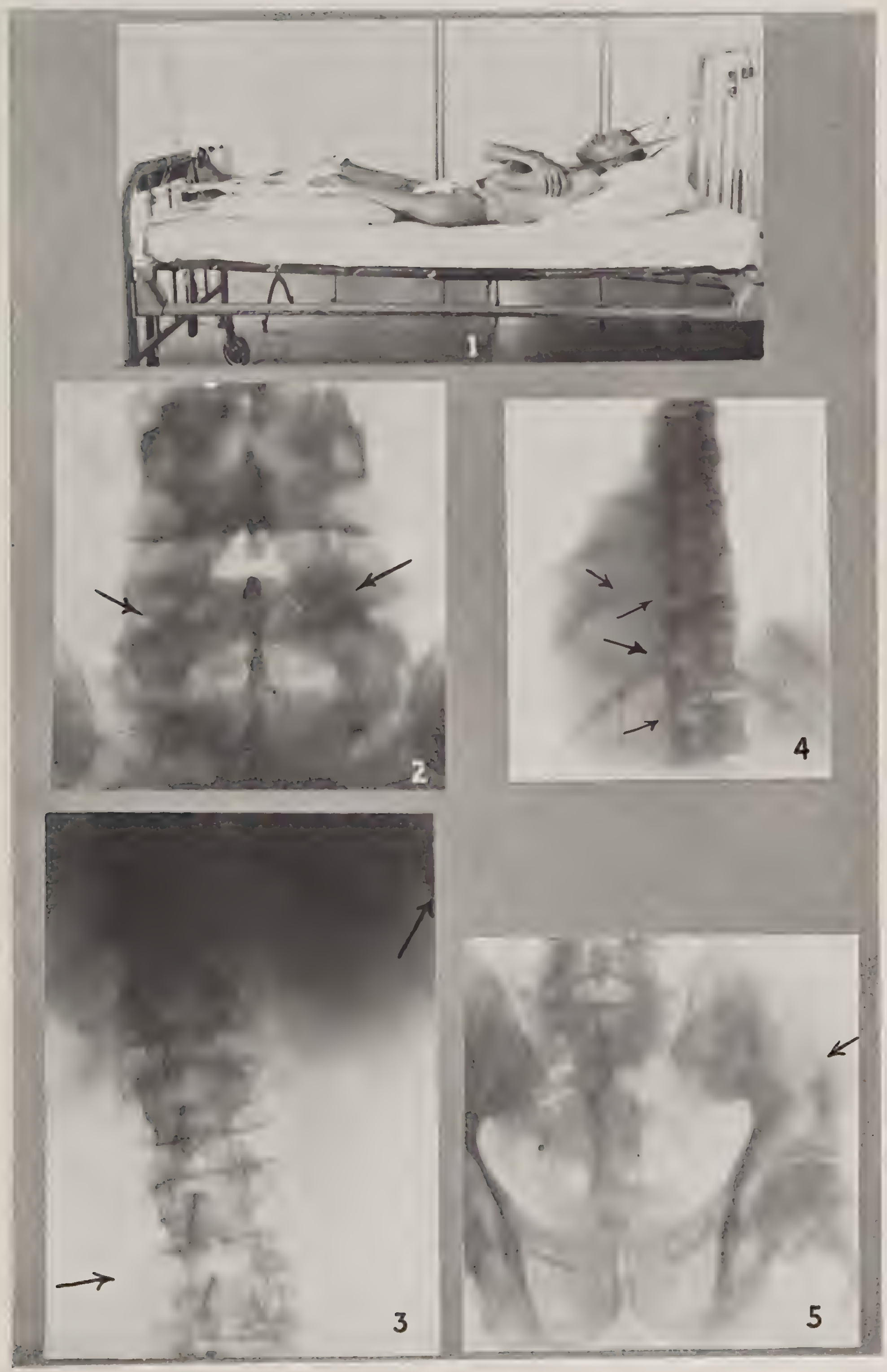

PLATE LXXI

very slowly and the patients are considerably tormented by neuralgias of all kinds, intercostal or sacrolumbar. In those instances operative fusion will hasten the ankylosis and may be undertaken as a symptomatic measure. Either the bone inlay graft of Albee, or the spinal fusion method of Hibbs may be applied to good advantage (see Chapter V).

(2) *Neuralgias.*—The neuralgic complications, such as sciatica, or occipital neuralgia, are to be treated with the conservative means of heat, diathermy and massage; persistent cases of sciatic neuralgia may call for injections of normal saline solution, or urea hydrochloride (Hertzler); in extreme cases operative stretching or neurolysis of the sciatic nerve may be indicated (for Technic see Chapter V). Finally, there remain cases of occipital neuralgia, sometimes so severe and persistent, that one must resort to the resection of the greater occipital nerve from the 2nd intervertebral foramen. The nerve can be reached readily from a semicircular incision over the lower occipital ridge. This incision will bare the trapezius, and, beneath it, the semispinalis muscle. The nerve can be seen to leave the foramen just at the lower border of the inferior oblique muscle which runs from the 2nd cervical spine to the transverse process of the atlas; it can be followed up to the intervertebral foramen and can there be resected (Plate LXVII, 4).

VI. COMMENT ON CHAPTER IX: CHRONIC ARTHRITIS OF THE SPINE

The more one views chronic arthritis of the spine as a systemic disease, with the spinal manifestations merely as the cardinal symptom, the better justice can be done to the patient in formulating the plan of treatment.

Focal infections, we believe, play an important rôle in all types; but the kind of infection varies with type and age. In children, infections of the upper air passages, especially of the sinuses are all important in this respect; in adults it is the teeth, the genitourinary and gastrointestinal tracts. Toxic metabolic factors come next; they are generally caused by intestinal insufficiencies, rarely by individual idiosyncrasies (protein). Visceroptosis is more often the cause than the effect of intestinal insufficiency; it is, at any rate, a link in a vicious circle.

The effect of endocrines upon arthritis of the spine is uncertain. There are indications, in some cases, of the influence of thyroid and ovarian function.

It follows from all this, that if a good deal of general and special examinations precede or at least accompany the treatment of the spine proper, many potential causes for the spinal affection will be unearthed. The point is to evaluate these properly as to their etiologic importance as foci. Here, we believe, one should not go beyond reasonable "probabilities" and should leave mere "possibilities" alone. This will save many teeth from being extracted.

On the other hand, one should be more impressed with the interrelation between spondylarthritis and general health; that is, with the necessity of hygienic measures and the restoration of body balance; this means regulation of diet and elimination by massage, support, outdoor life, etc.

As in all arthritic patients, so also in spondylarthritic patients, one should never forget the psychic and emotional factors. Surroundings mean a great deal to those patients. They need encouragement and cheer; they also need useful occupation as part of the treatment.

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CHAPTER X

TUMORS OF THE SPINE

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V. Comment on Chapter X: Tumors of the Spine

Tumors observed in the spinal column belong either to the benign or the malignant type. In the latter group secondary or metastatic tumors prevail over the primary.

I. CLASSIFICATION

a. Primary, Benign

To the primary benign tumors belong the osteoma and osteochondroma; these tumors are found in all regions of the spinal column from the odontoid process to the sacrum. Other, less frequent benign tumors, are hydatid cysts and dermoids; the latter are observed in connection with spina bifida occulta.

b. Primary, Malignant

Primary malignant tumors of the spine are likewise rare. They occur as fibrosarcomas and endotheliomas. These tumors have their origin mostly in the vertebral bodies which soon become infiltrated and replaced by tumor growth. Destruction and collapse of the vertebral body follows. The myeloma of the spine also occurs occasionally as primary tumor.

c. Secondary Malignant Tumors

The majority of malignant growths of the spine are secondary: most common among these are carcinoma and sarcoma, less frequent is the secondary myeloma of the vertebrae.

II. GENERAL PATHOLOGY

1. Pathogenesis

a. Route of Metastasis.—According to general conception the usual way of tumor deposit is the hematogenous route. The propagation of tumor masses by the lymphatic system is doubtful. It is impossible to demonstrate lymphatics in any part of the bone marrow and material injected through the lymphatics, while it can be forced through the compact bone, is held back by the endosteum. This casts doubt upon the theory that metastases in bone can be the result of the centrifugal permeation of the lymphatic vessels. It was Recklinghausen[30] who first had the conception that the metastases in bone were the result of malignant emboli in the marrow capillaries. There is, indeed, preponderating evidence in favor of the claim that bone metastases are blood borne and that they are due to the lodgement of malignant emboli in the bone marrow (Joll[19]). It follows also that such tumor particles must be actually in the blood stream in order to reach the place of secondary localization.

b. Primary Localization.—It is of interest to follow the statistics on the incidence of the primary tumor in the different localities. In point of frequency, we find that carcinoma of the breast plays probably the most important rôle. Williams[36] found, among eight hundred and ninety-three autopsies on cancers of the breast, that not less than 26.5 per cent of these secondarily involved bone. Of the cases with bone involvement 19.1 per cent showed metastases in the vertebrae.

The thyroid gland comes next as primary seat of metastatic tumors of the spine. Bergmann[3] found among sixty-five cases of malignant tumor of the thyroid metastases as follows: in 11 cases metastases of the vertebrae; in 18 cases metastases in the sternum; in 11 cases metastases in the rib; and in 8 cases metastases in the pelvis.

Of lesser importance is malignant disease of lung and bronchi. Adler,[1] among three hundred and seventy-four cases, reports fifty-seven bone metastases with special tendency to involve the rib, the spine, the skull, and the sternum.

Malignancies of the testicle, especially sarcoma, also may metastasize in the spine. Among thirteen cases of sarcoma of the testes Butler found secondary metastases in bones in three.

Of particular interest are the metastases which follow apparently benign goiter. Cohnheim,[6] who first called attention to this occurrence, describes a case of a man thirty-five years old with a simple colloid goiter which produced metastasis in the 2nd, 3rd, and 4th lumbar vertebrae, and others in the lungs, in the glands, and in other bones. He explains the malignant degeneration of an apparently benign goiter tumor by external influences, constitutional weakness, etc. Many others have described similar malignant metastases in the spine following an apparently benign goiter tumor. Middledorpf[25] reports a woman of fifty-six with metastasis in the 3rd and 4th lumbar, destroying the bodies and forming a great tumor mass; there were metastases in other bones, some leading to spontaneous fractures. Jaeger reports a woman of sixty-nine with a malignant tumor of the lumbar spine, a part of which was removed at operation. Histologically it was found to be a metastasis of the thyroid. Another case showing a tumor of the 3rd dorsal vertebra which narrowed the spinal canal is described by Hollis.[18] This tumor also metastasized in the cerebellum and the falx cerebri, and all tumors resembled goiter.

Malignancy in the spine following tumor of the prostate is also comparatively frequent. This growth has, perhaps, the greatest tendency of all tumors to metastasize in bone and the metastases are especially characterized by their osteoplastic tendencies. Malignant hypernephroma in the vertebrae has been reported. Primary carcinoma of the bronchial system is uncommon, but when it occurs it is very apt to produce metastases in the vertebral column. Joll[19] describes a specimen in a patient thirty-five years old suffering from cancer of the rectum with metastasis in sternum and spine.

Summing up, the organs supplying the primary tumor are, according to frequency: the breast, thyroid, uterus, stomach, gall bladder, and prostate.

c. **Frequency Statistics.**—Schlesinger[31] in an extensive analysis based upon 35,000 autopsies found one hundred and thirty-five tumors of the spine and its contents, of which 50 per cent were located in the medulla, 33 per cent in the meninges, and 17 per cent in the vertebrae. The tumors of the spine contributed 0.3 per cent of all tumors, and the majority of spine tumors was found to be malignant. By far the greatest portion of the malignant tumors, again, are secondary and reach the spine by way of metastasis or by contiguity from other organs.

Among bone metastases in general, the vertebral column occupies a prominent place. According to the statistical analyses of Joll 31.6 per cent of all bone metastases were vertebral against 20.4 per cent in the ribs, and 14.7 per cent in the sternum. The metastatic tumors in the vertebral column may be single or multiple.

d. Statistics Relative to Location in the Spine.—Cancer of the spine has a predilection for the dorsal and lumbar regions, attacking one or several vertebrae, not by a process of diffusion, but by the development of several independent metastases. As a rule, these metastases are located in the center of the body of the vertebrae and from here the process spreads toward its periphery, destroying the spongious portion of the vertebral bodies. The cortex resists for a time the invasion of the neoplasm, but finally it also becomes destroyed and the vertebral body breaks down. This process is sometimes retarded by the fact that destruction of the vertebral body is accompanied by new formation of bone. We speak, then, of an osteoplastic tumor, especially of the osteoplastic carcinoma, in contrast to the osteoclastic tumors in which there is no new bone formation. When finally the barrier of the cortical substance has been broken down, the tumor may further invade the posterior portions of the body, the lateral processes, the arches, or the spinous processes.

2. The Symptoms of Spinal Tumors (General)

Symptoms produced by spinal tumors in general depend upon their nature, upon their location, and upon their structure. One may distinguish between the symptoms of local character and symptoms due to disturbance of function. The disturbed function manifests itself by compression symptoms of the medulla and by the appearance of nerve root symptoms. These are not always due to direct pressure, but may be indirectly caused by the deformity which follows the collapse and breaking down of the vertebrae. For instance, a malignant tumor of the vertebral bodies may, in breaking down, produce a severe deformity of the spinal canal and subsequent compression of the medulla.

The symptoms referable to the bone lesion itself consist in local pain, spontaneous or produced by pressure, in the spinal deformity, and in a palpable tumor mass. Palpable tumors are mostly enchondromas, osteomas, rarely malignant neoplasms (carcinoma).

The symptoms referable to the cord lesions consist in cord compression, neuralgias, usually symmetrical, and in the root symptoms. The latter are observed in 60 per cent of the cases.

Trophic symptoms are frequently found in secondary metastatic tumors of the spine.

The local symptoms of the tumor of the spine are also of great diagnostic interest. There may be a great discrepancy between the local symptoms and the nervous complications. Sometimes a large tumor may cause very little compression symptoms, and in other cases, grave compression signs may follow an apparently insignificant neoplasm.

Deformity.—Many tumors of the spine produce deformities in the shape of kyphosis, or kyphoscoliosis. These are, as a rule, cases of malignant tumors, primary or secondary, situated in the body of the vertebra. According to the nature of this tumor the deformity develops rapidly or slowly, but at a certain point a breakdown of the vertebrae under the incumbent body weight may be expected. Often several of the vertebrae become invaded and destroyed simultaneously; the deformity then assumes the type of an arcuar kyphosis instead of an angle, as is the case when only one of the vertebrae breaks down. When the neoplasm affects the posterior portion of the vertebrae, that is, the arches, laminae, and the apophyses, it is not so likely to produce deformity.

Most of the cases in which the posterior portions of the vertebrae are involved are benign tumors. These, also, may produce a medullary compression (osteoma).

3. The Prognosis (General)

The prognosis of the benign tumor depends entirely upon its secondary effect upon the nervous structures.

The prognosis of the malignant tumor is generally unfavorable. Schlesinger estimates the average duration of life in malignant tumor at nine and one-half months in carcinoma, and eleven months in sarcoma, after the beginning of symptoms. Three and one-half years was the longest period observed in carcinoma and one and one-half years in sarcoma.

III. SPECIAL PATHOLOGY

1. Benign Tumors

a. **Osteoma and Osteochondroma.**—The most frequent tumor of the benign type seen in the spine is the osteoma and the osteochondroma. The osteoma may involve the spine at any level; that of the cervical spine is most frequent. Henderson[17] reports a case of a boy ten years old complaining of dull ache in the right posterior part of the neck aggravated by sudden jerks and motions. Here, the x-ray picture revealed a round bony tumor 5 cm. in diameter which seemingly arose from the right side of the 3rd cervical spinous process, and possibly from the articular process. This tumor was encapsulated and upon microscopic examination was found to be a globular osteoma. It had a dense capsule and trabeculae running into the surrounding muscle tissue, and a trabeculated framework, but contained no cartilage cells.

Bland-Sutton[5] describes an osteoma situated at the anterior surface of the odontoid process of the axis. This tumor caused death by pressing upon the spinal cord. On the whole, the osteoma of the spine is infrequent.

b. The Hydatid Cyst. Echinococcus Cyst.—Among seventy-five cases collected in the literature by Chignozzi the spine was involved in 1 per cent; according to Frey, the spine is the seat of metastatic hydatid cysts in 1.5 per cent, the pelvis in 4.5 per cent of the cases. In the series of Gangolphe there were, among fifty-two cases of bone localization of echinococcus, eight of the vertebral column and eleven of the pelvis, the latter giving uniformly a somewhat higher percentage than other bones.

There are two stages of growth to be distinguished: in the first period, the period of infiltration, there are numerous small vesicles showing eccentric growth and producing dilatation of the Haversian canals. In the second period the tissue succumbs slowly to necrosis and, by confluence of numerous necrotic foci, a great cavity is formed.

Three pathologic types can be distinguished (Bland-Sutton[5]): one in which the cyst is located entirely within the canal, either inside the dura or in the loose areolar tissue between dura and bone; one in which the cyst arises from the vertebra and extends into the canal; and one in which the tumor starts from the adjacent structures, then involves the spine and extends into the spinal canal.

Most of the tumors have a slow and gradual tendency to extension and invade not only the osseous tissue but also the neighboring soft parts.

The most outstanding clinical symptoms are the signs of cord compression.

In the majority of cases of longer duration, the process has already assumed such extension that operative removal seems impossible. Then the surgeon must content himself without treatment or limit it to simple opening of the subcutaneous mass, an insufficient and unsatisfactory method. Sometimes the tumor is sufficiently favorably located, for instance, in the sacrum, so that a more radical removal of the tumor can be undertaken. It seems that only those interferences were successul in which a more or less radical removal of the osseous focus was possible, and that the radical treatment of the tumor is the only sufficient one.

c. The Dermoid Cyst of the Spinal Column.—Dermoids of the spine are very rare. They usually form in connection with spina bifida, where they are seen over the spinal defect; only rarely are they attached to the spinal canal. In a case observed by Hale White a laminectomy was performed in order to relieve pressure symptoms of a tumor which grew into the spinal canal and pressed upon the spinal cord. This tumor proved to be a dermoid cyst. The operation, however, was not successful.

d. Fibroma and Chondroma of the Spine.—These tumors are likewise very unusual. The fibroma may attain a very considerable size and then cause symptoms of spinal compression or root irritation.

The chondroma of the spine is a cartilaginous tumor, which may secondarily undergo degeneration and become myxomatous, calcareous, or fatty.

True cyst formation in these tumors of the spine has been observed. A case of Marshall's[23] demonstrated an abnormal growth in the cervicodorsal and lumbosacral region of the spine, as well as in the scapula and the long bones. Upon incision of this tumor it was found to be of benign character with irregular groupings of hyalin cartilage and bone trabeculae surrounding the marrow.

e. Multiple Cartilaginous Exostoses (Plate LXXXIII, 4).—Involvement of the vertebrae in multiple cartilaginous exostoses is uncommon. These cartilaginous tumors are usually disseminated over the long bones, are not uncommon also in the ribs and in the pelvis, but only rarely affect the vertebrae, and then the superior and inferior contours of the bodies are usually the sites involved (Phemister[28]).

2. Primary Malignant Tumors of the Spine

a. The Myeloma.—Myelomatosis was first described in 1873 by Rustitzki. It is also known as Kahler's disease, after Kahler, who in 1889 was the first to call attention to the characteristic clinical and pathologic features. It consists in formation of multiple, gray, or red-yellow tumors, starting from the bone marrow and extending into the bone substance which then undergoes rarefaction. The vertebrae are the most common seat of these tumors; next are the sternum, ribs, and then the long bones. The disease is described by Ewing[11] as a specific malignant tumor of the bone marrow characterized by multiple foci of origin and known as multiple myeloma. Clinically, it resembles most closely tuberculosis of the spine (Osgood[27]).

(1) *Pathology.*—It is a neoplastic disease characterized by foci of growth which arise at different parts of the marrow system, the individual tumor springing from certain primitive cells of the blood forming class (Symmers[34]). It is a specific malignant tumor of the bone marrow and has a specific structure of plasma cells, or their derivatives (Turner[35]). The tumor often penetrates the surrounding tissues. The x-ray picture shows evidence of melting down of bone substance, blurring, and defects similar as are observed in carcinoma. The tumors present small multiple nodules which vary greatly in size; they grow and become confluent until a state of diffusion and infiltration is reached. The original, multiple tumors are limited to the bony system, but metastases are formed, though not frequently, in other organs. The tumor in the spine may produce deformity, kyphosis, occasionally even collapse or spontaneous fracture. The presence of Bence-Jones bodies in the urine is an important differential point.

(2) *The Symptoms.*—The disease occurs most frequently in males between twenty and sixty and usually terminates fatally in from six to eighteen months. The symptoms are rheumatic pain in the back, trunk and extremities. There is loss of weight and anemia. In the upper cervical region the presence of myeloma in the bone marrow of the vertebrae is not uncommonly manifested by neuritic pain in one or both arms, sometimes associated with

motor or trophic disturbances. In the lower lumbar spine similar symptoms arise from involvement of the sacrolumbar plexus. In later stages emaciation, cachexia, and finally paresis and muscle atrophy occur, and spontaneous fractures have been observed (Levison and Moeller[21]). Osgood reported three cases of extensive involvement of the vertebrae. The gross specimens in these cases showed a very thin cortex, and the dark red tissue of the tumor mass was somewhat vascular and contained trabeculae. The latter undergo gradual absorption. The tumor never produces bone; areas of necrosis occur and extensive fibrosis seems to be the natural termination of the process (Osgood). Up to 1906, two hundred and four cases of myeloma of the spine were collected by Martini,[24] all adults, the youngest being twenty-four years. The places of predilection were the vertebrae, the sternum, the ribs, skull, clavicle, scapula, ileum, i.e., the flat and short bones. Rarely are the tumors found in the ends of the long bones.

According to Berkheiser[4] multiple myelomata occur also in children, where the lesions are larger, though not so disseminated. He reports two cases involving the spine. The presence of Bence-Jones bodies or of proteinuria is not pathognomonic, but it is found with greater frequency in older patients than in children.

The prognosis of multiple myeloma is unfavorable. Of two cases reported by Scott[32] showing the characteristic x-ray findings and Bence-Jones proteinuria, one terminated fatally after nine months, while the other was still living and symptomatically improved after four years. Both cases were associated by low kidney function, uremia, and high nitrogen retention in the blood. One case had demonstrable areas of disease in the cranial bones as well as in the lumbar spine.

b. The Chloroma.—The chloroma or "green cancer" is a neoplastic disease of the hematopoetic system, closely related to sarcoma. It presents a blood picture and a clinical course which is similar to that of acute lymphatic leucemia. It is considered by Mallory as a rare form of myelogenous leucemia. Bedell[2] found only ninety cases in the literature up to 1922. A case is reported by Darnall[8] in which the chloroma was situated in the spongious substance of the sacrum, forming a large tumor infiltrating the entire bone. This tumor not only spreads throughout the bone, but also causes metastases by the hematogenous route. In Darnall's case there was increase in the anteroposterior diameter of the sacrum and there was pain radiating down the thighs, paralysis of the bladder and of the rectum. There were metastases of the kidneys and of the glands. The hemoglobin dropped to 15 per cent.

c. Primary Giant-cell Sarcoma.—Lewis[22] reports seventeen cases of primary giant-cell tumor of the spine in the literature, including one case of his own. The ages of the patients ranged from seventeen to forty years. The cervical spine was involved in one, the dorsal in six, lumbar in seven, and the sacrum in one case. In no case were there metastases, but local recurrences were seen in some cases. Persistent paraplegia was observed in several instances. Rasch[29] reports a case of primary giant-cell sarcoma of the 10th dorsal with severe pain, gradual signs of cord compression, myelitis, and bed sores. The x-ray picture closely resembles that of tuberculosis of the spine. In the case reported by Rasch the giant-cell sarcoma resulted in almost complete destruction of the 10th dorsal vertebra. Death occurred after eighteen months. The removed tissue showed calcareous particles, large round and spindle cells, scattered giant cells, and polymorphism and nuclear hyperchromatosis, characterizing the tumor as a giant-cell tumor.

d. Primary Osteogenic Sarcoma.—Primary sarcoma of the vertebral column is rare, while secondary deposits of sarcoma and carcinoma occur with comparative frequency (Bland-Sutton). A case of primary sarcoma of the spine described by Kleinberg[20] is of special interest because of the difficulty of early diagnosis. The tumor was situated about the 9th, 10th, and 11th dorsal vertebrae and there were no other lesions in any part of the body. There were no Bence-Jones bodies in the urine. The x-ray picture showed extensive destruction of the body of the 10th dorsal vertebrae, but very little change in the intervertebral discs above and below it. This, Kleinberg considers a differential point against Pott's disease in which the intervertebral discs are destroyed early in the disease. Other points of differential importance are the rapid destruction of the vertebrae, and the early appearance of cord symptoms. It is believed that a distinction between primary and secondary tumors of the spine can be made roentgenologically upon the grounds that the latter never involve the surrounding soft tissues and that a shadow extending into the neighboring soft parts allows the diagnosis of primary malignant tumor to be made (Kleinberg).

3. Secondary Malignant Tumors of the Spine

a. Sarcoma (Plate LXXII, 1, 2, 3, 4, 5).—The secondary sarcoma of the spine is much more frequent. It represents a hematogenous secondary deposit, or takes its start from the fibrous tissue in the neighborhood of the spine.

Contrary to general opinion the prognosis of the vertebral sarcoma is not necessarily fatal (Guleke[15]). Guleke observed a case of fibrosarcoma probably starting from the periosteum of the vertebral canal in which root pain existed for ten years before the operations. He removed the tumor which extended from the 6th to the 9th dorsal and had caused severe compression of the spinal cord having grown also into the posterior mediastinum. This patient was observed for eight years. There are other cases on record in the literature with operative cure of seven, eleven, and twenty-seven years. The diagnosis in some of these cases may be doubtful. Davies-Colley[7] reports a case of fusiform sarcoma of the laminae of the dorsal vertebrae with pressure upon the cord in which laminectomy was followed by apparent cure.

Cases of ossifying osteosarcoma are described. Crainz[7] reports a tumor

PLATE LXXII

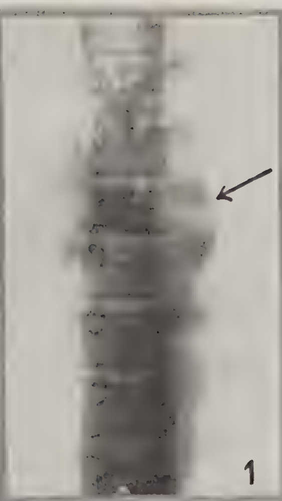
Fig. 1.—Sarcoma involving 5th dorsal (see Fig. 2).

Fig. 2.—Lateral view of case in Fig. 1. (Note preservation of intervertebral discs in both views.)

Fig. 3.—Metastases from sarcoma of sternum. (Note collapse of 5th lumbar and destruction of sacrum.)

Fig. 4.—Sarcomatous metastases to ileum.

Fig. 5.—Localized areas of increased density. Osteoplastic metastatic lesion. Primary site prostate.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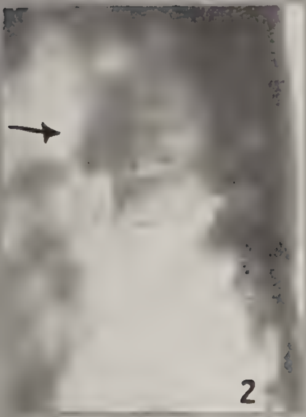
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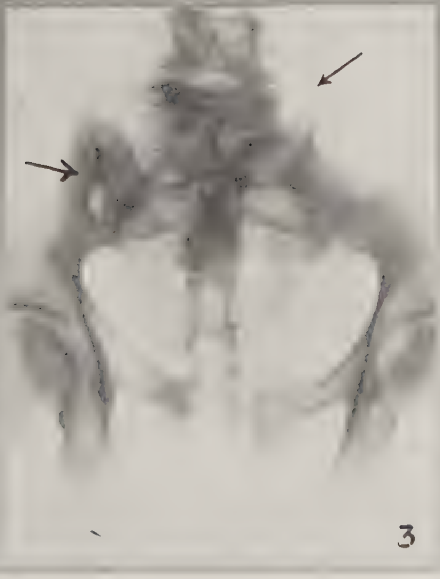
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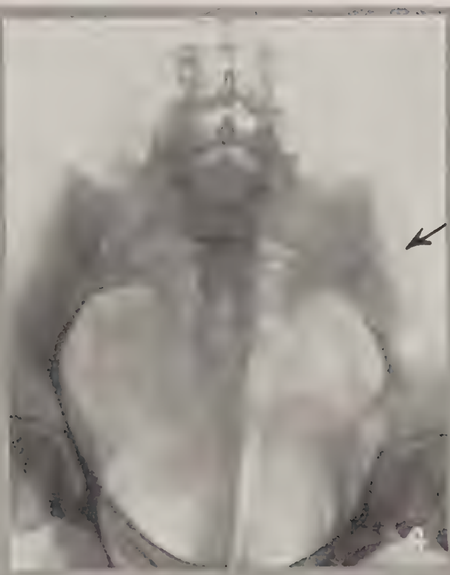
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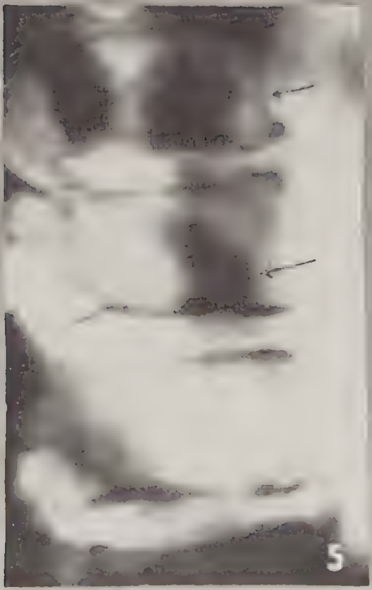
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PLATE LXXII

located in the lower cervical spine and starting from the laminae, which, by its mere size produced a scoliosis of the cervical spine. This tumor proved to be an ossifying type of osteosarcoma.

b. Carcinoma (Plate LXXI, 3, 4, 5).—

(1) *Pathology.*—Carcinoma of the spine is most frequently metastatic, following carcinoma of the breast, the uterus and the prostate. Malignant or benign tumors of the thyroid have been mentioned previously as the primary focus for carcinomatous tumors of the spine. The frequency with which the spine is involved in metastatic malignant growth is, according to Fränkel,[14] as high as 20 per cent and most frequent are the metastases following mammary carcinoma.

The x-ray picture shows that the bone tissue is very poor in lime salts, its contours are blurred, washed out, the spongious meshes are wider, the vertebrae involved appear blurred and there are diffuse defects in structure and contour.

(2) *Symptoms.*—In many of the individuals which are seen early before the disease has reached the spinal cord, the subjective symptoms are vague and cannot well be localized.

According to Oppenheimer[26] the early symptoms are of the nature of root irritation and are distinguished from peripheral nerve lesions. Here belongs the bilateral sciatica. When the spine is afflicted at a higher level the symptoms are more segmental in character: girdle pain, intercostal neuralgia. The pain is always radiating and is aggravated by motion. The symptoms of radiation appear with or without spinal rigidity.

A compression of the vertebral body may also occur early in the disease and may be detected, before direct radiographic evidence is at hand, in the change of relation between the adjacent spinous processes of the affected vertebrae (Oppenheimer[26]). Usually there is also a diminution in the height of the vertebrae. Slight changes in the outlines of the body sometimes are shown in the oblique picture as the first x-ray signs. With advancing destruction the signs of deformation of the vertebra and collapse of the body become quite evident in the radiogram.

A peculiar x-ray picture is seen in the so-called osteoplastic carcinoma of Recklinghausen,[30] described first in 1891 (Plate LXXII, 5). This type usually follows carcinoma of the prostate, sometimes carcinoma of the breast. It is seen most frequently in the lower dorsal and lumbar sections. A description of the x-ray findings in osteoplastic carcinoma of the spine is given by Dietlen.[10] In principle, there are changes in form and position of the bodies of the vertebrae such as one might see in spondylitis deformans. Destructive processes in the body of the vertebra are present, but are in the background in comparison with the osteoplastic changes. In view of the strong resemblance to spondylitic conditions Dietlen believes that a differential diagnosis in these two conditions cannot be made in the living from the x-ray picture. Heineke[16] observes that ossifying metastases of carcinoma are not so rare, most frequently following tumors of the prostate, the uterus, or the breast. Ossifying sarcomatous metastases and ossifying secondary hypernephromas are much rarer.

IV. TREATMENT OF TUMORS OF THE SPINE

Only in occasional instances of benign tumors a radical treatment is possible. In the malignant tumors, which constitute the great majority of spinal tumors, the treatment is merely symptomatic. The main object of it is to relieve the compression symptoms and pain.

1. Conservative

A plaster of Paris bed in which the patient reclines protects the spine to a considerable extent and prevents its collapse. In some cases it gives, in a measure, relief from pain. Extension is usually poorly tolerated.

X-ray therapy undoubtedly has some effect upon sarcomatous and myelomatous growth, but it is only temporary. One often finds in the beginning a disappearance of the neuralgic and root symptoms, but with their return these measures prove ineffective.

2. Operative

In view of the urgent necessity of relieving the patient from excruciating pain operative means must be resorted to frequently.

a. Simple alcohol injections into the spinal canal have been performed apparently with occasional satisfactory results.

Of the operative procedures, the resection of parts of the vertebral bodies, the laminectomy, the resection of the posterior root, and the section of the anterolateral tract (Spiller and Martin[33]) come into consideration.

b. Resection of Vertebral Bodies.—The bodies of the lumbar vertebrae and the upper portion of the sacrum can be resected transperitoneally; the bodies of the cervical vertebrae can be reached through the lateral cervical triangle. In the dorsal section costotransversectomy as a preliminary operation is necessary for the approach of the body (Chapter VI).

c. Laminectomy is necessary as a preliminary step to reach the posterior surface of the vertebral bodies (see Chapter VI). Tietze reports a case of resection of a compressing carcinoma of the 3rd lumbar vertebra by laminectomy and excochleation, with relief of pain. In the case of Israel the 6th dorsal body was reached after costotransversectomy and a sarcoma was resected with relief of pressure symptoms. Large resections of sarcoma are described by Schloffer (3-6 cervical arches) and H. Kümmell (4th dorsal). Of three cases reported by Guleke[15] one, in which the 5th to the 9th arches with the 7th and 8th transverse and articular processes, and head and neck of 7th and 8th rib, were resected for fibrosarcoma, remained well for three years.

d. Resection of Posterior Roots (Plate LXXIII, 1).—As a pain relieving operation Foerster's[12] resection of the posterior roots may be considered.

PLATE LXXIII

Fig. 1.—Division of anterolateral tracts. Method of Spiller-Martin (Elsberg).

Fig. 2.—Resection of the posterior spinal roots. Sensory nerve raised (Elsberg).

Fig. 3.—A.L. anterolateral tract. L.D. dentate ligament (Elsberg).

Fig. 4.—Multiple cartilaginous exostoses involving spine.

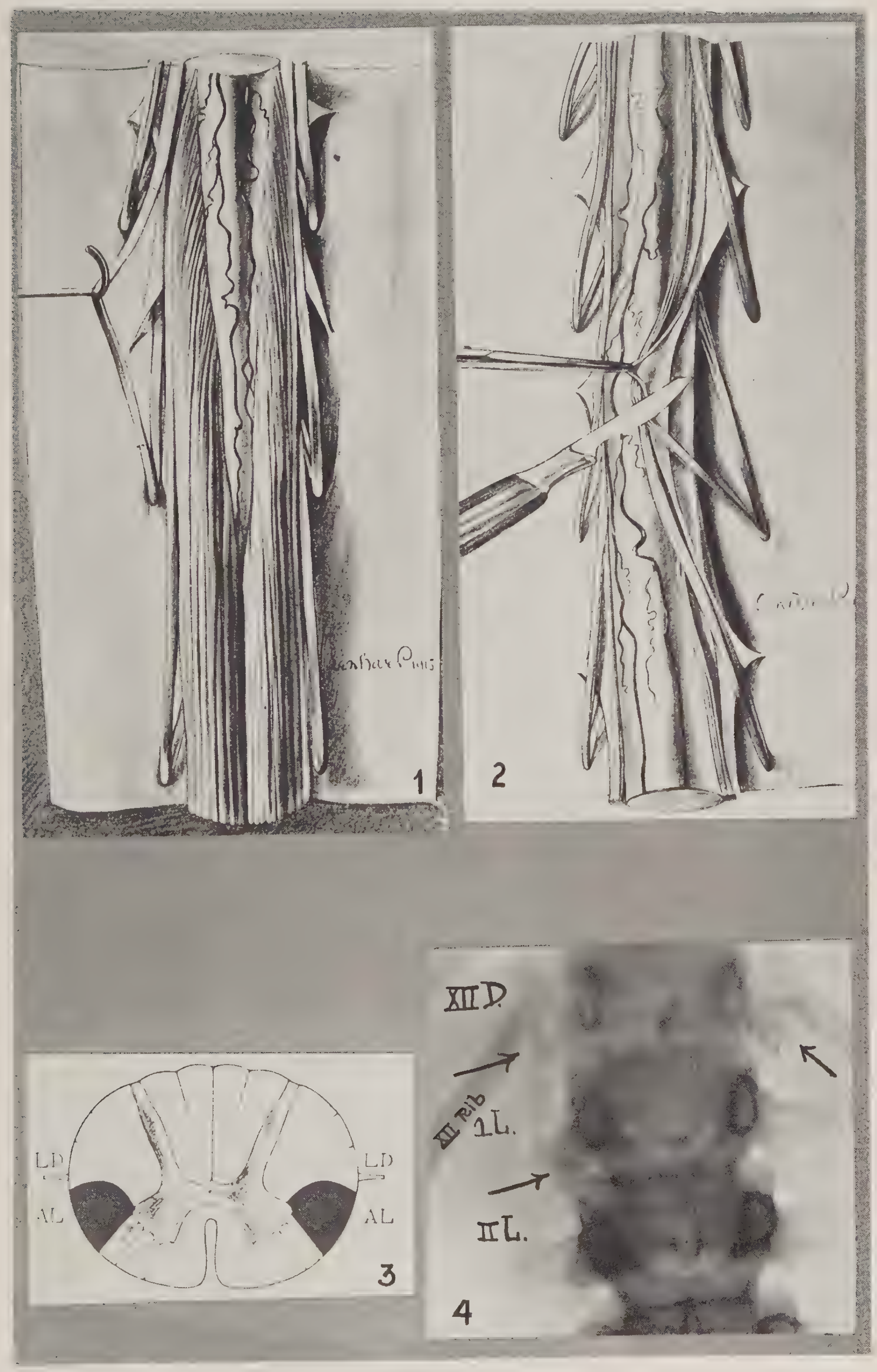

PLATE LXXIII

These roots are approached by laminectomy. After opening of the dura they can be identified by the situation of the denticulate ligament, which divides the posterior, or sensory, from the anterior, or motor roots.

e. Section of Anterolateral Tract (Plate LXXIII, 2, 3).—Spiller and Martin[33] recommend for the relief of uncontrollable pain the section of the anterolateral tract of the cord. The section of this tract abolishes temperature sense and pain in the contralateral body half below the operation, while the mobility is not, or only a little, affected. The section is carried out with a fine cataract knife inserted just in front of the denticulate ligament. Favorable reports on the pain-relieving effect of this operation are rendered by Spiller and Martin,[33] Foerster,[12] Tietze and others.

V. COMMENT ON CHAPTER X: TUMORS OF THE SPINE

With the exception of sporadic cases of benign tumors, principally of the osteoma and osteochondroma class, the bulk of spinal tumors are malignant. Of these, again, the secondary metastatic tumors preponderate over the primary malignant growths.

It follows that in, by far, the greatest number of instances the treatment can only be symptomatic for the relief of pain and of spinal cord compression. Of these two, pain is the more serious and more compelling symptom. It is so intense and so uncontrollable, even by opiates, that heroic surgical measures are fully justified if they hold out a fair promise of relief. Operative removal of the constricting portion of the tumor is technically very difficult and only few successful cases are on record. Even this can only be considered as symptomatic, not as causative treatment.

Resection of the posterior roots, after Foerster, or better, the section of the anterolateral tract on both sides, after Spiller and Martin, is often attended with striking relief. Such measures should be considered more frequently; while they hardly prolong the life, they offer tremendous relief to the patient, who would otherwise be doomed to await a lingering death in frightful agony and suffering.

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APPENDIX

SYNOPSIS OF THE ANATOMY OF THE SPINE

To appreciate the complex and intricate construction of the human spine one must view it in the light of the various and difficult functions it is meant to perform:

As a **sustaining rod** which maintains the upright position of the body, carries its weight, and from which the thoracic cage is suspended.

As a **rod** planted firmly into the pelvic ring upon which it balances.

As a **post** of anchorage for the powerful musculature of the shoulder girdle and the upper extremity.

As a **buffer spring** which receives and distributes in rapid and endless sequences innumerable jars and jolts associated with the dynamic functions of the body.

As a **casing** which safely encloses the most delicate structure of the body, the spinal cord, and yet provides a free and unincumbered path for the spinal nerves to reach their peripheral destinations.

And, above all, as an organ of great **flexibility** which produces momenta of force and receives, concentrates, and transmits those originating in other parts of the body.

To accomplish all this the spine must be organized as a system of many links, movable against each other and still so secured by ligamentous and muscular apparatus as to maintain its form and position, segment to segment, against all external influences.

I. THE VERTEBRAE

The normal (modal) number of the presacral segments of the spine is 24: 7 cervical, 12 dorsal and 5 lumbar. The anterior portion of the segments (bodies) constitute the so-called anterior column; the posterior portion (arches) with their appendages (the spinous, transverse and articular processes) constitute the posterior column of the spine. Anterior and posterior columns are joined together by the pedicles, short stubs between the posterior body wall and the articular processes.

From the first cervical down to the last lumbar, the vertebral body constantly increases in mass and volume, corresponding to the increase of weight-bearing stress from above downward. In the sacrum, which is the immovable portion of the spine, being wedged firmly between the two halves of the pelvic ring, the mass and volume of the 5 segments rapidly decrease from above downward, as do also the 3 segments of the coccyx; so that the entire spine, in the frontal plane, appears as two isosceles triangles, pointing in opposite directions, with a common base. One, long drawn out, is the movable spine, the other short, is the sacrum and the coccyx.

We further notice that the normal spine has four curves in anteroposterior direction (Plate X, 1, 2): a cervical curve, convex in front; a dorsal curve, convex behind; a lumbar curve, convex in front, and again a curve embracing sacrum and coccyx, convex behind; for the stability of the spine and for its function as an elastic spring, this is of fundamental importance (see Chapter III). The posterior column or arches carry three apophyses or processes; the spinous process which is rudimentary in the first cervical (tuberculum posticum atlantis), and is bifid in the other cervical vertebrae (Plate LXIX, 1); the transverse process, which in the cervical segment fuses with the costal element leaving a small foramen between as passageway for the vertebral artery; and the articular processes, an upper and a lower for each side which carries the facets of the intervertebral articulations. From the first cervical down to the first lumbar segment, where it ends, the spinal cord also diminishes in caliber excepting for the two regions near the cervicodorsal and lumbodorsal levels of the spine, where the cord becomes enlarged to form the cervicodorsal and lumbodorsal enlargements. Below the level of the disc between first and second lumbar vertebrae, the spinal canal contains only bundles of spinal nerves, known as cauda equina, and the meninges (Plate LXXIII, 1). Consequently the spinal canal becomes relatively smaller, and in certain regions also absolutely smaller compared with the volume of the vertebral bodies which increases from above downward (Plate LXXVI, 2). This becomes especially noticeable in the atlas. This vertebra has lost part of its body to the 2nd cervical, the axis, by fusion of body with that of the axis, to form the odontoid process. Only the anterior portion of the 1st cervical body persists as the anterior arch of the atlas. Landmarks: a bare finger's width below and in front of the mastoid process is felt the tip of the transverse process of the 1st cervical vertebra. This process is opposite the angle of the jaw. The cricoid cartilage is opposite the 6th cervical vertebra and its transverse process; it denotes the lower limit of the larynx and pharynx and the beginning of the trachea and esophagus, and is also opposite the 2nd cervical ganglion. The episternal notch is opposite the 2nd dorsal vertebra.

The junction of the first and second pieces of the sternum, or the angle of Louis, is opposite the junction of the 4th and 5th dorsal vertebrae. The junction of the second and third pieces of the sternum is opposite the 9th dorsal vertebra.

The lowest point of the 10th rib is opposite the junction of the second and third lumbar vertebrae.

A horizontal plane passed through the crests of the os ilei strikes the 4th lumbar vertebra.

The posterior inferior spine marks the termination of the horizontal limb of the sacroiliac joint (Prentiss).

II. THE ARTICULATIONS

a. Between Vertebral Bodies (Plates LXXIV, 4; LXXV, 4)

Movement between the vertebral bodies is made possible by the interposition between them, of an elastic structure, the intervertebral discs (see Chapter III). These discs consist of a fibrous ring in which bundles of fibers run in different directions: the annulus fibrosus, and of a central, soft and movable, hyaline core, the nucleus pulposus (Plate LXXIV, 4). In all motion of body against body some of the fibers yield according to their direction; and in asymmetrical movement of the bodies against each other (side-, or for- and backward bending) the nucleus pulposus changes its position, shifting back and forward, or from side to side (see Chapter III).

The height of the intervertebral discs diminishes from above downward. At the apices of the physiologic curves of the spine they are also decidedly wedge shape; in the cervical spine they are higher in front; in the dorsal slightly higher in the back, and in the lumbar again, distinctly higher in front, corresponding to the convexities of the normal anteroposterior curves of the spine. The discs, accordingly, have the greatest share in the formation of the curves.

b. The Intervertebral Articulations (Plate XVII, 6)

Movement of the segments of the posterior column of the spine against each other occurs in the intervertebral articulations. Their articular facets are carried by the articular processes, an upper and a lower facet to each vertebral half.

In form and position the articulations vary in the different sections of the spine. In the cervical spine the articulations are in one plane; they resemble saddle joints, sloping from forward backward, 45-60 degrees against the horizontal. They allow motion in all three directions: forward and backward in the sagittal plane; sideways in the frontal, and rotatory in the transverse plane.

In the dorsal spine the joints are likewise flat, but converge strongly posteriorly; they approach more nearly a frontal plane; the arrangement of overlapping each other shingle fashion provides for forward flexion and rotatory motion, which is the motion peculiar to this section of the spine.

In the lumbar section the articular facets have a cylindrical curve, the upper concave, the lower convex. They approach in their arrangement the anteroposterior, or sagittal plane, allowing for lateral bending as the most favored movement in this section.

The atlantooccipital articulation (Plate LXXIV, 3) is formed by the condyles of the occipital bone and the articular facets of the atlas. These joint bodies are oval in shape with the long axes converging in front and running from above, outward and backward, to downward, forward, and inward.

The atlantoaxoid articulation (Plate LXXIV, 3) consists of four joints: (1) the articulations between the lower surface of the atlas and the articular surface of the axis, situated upon the body and pedicle of this latter vertebra, one articulation to each side; and (2) the articulations between atlas and odontoid process, one at the anterior and one at the posterior circumference of the odontoid process. The anterior articulates with a facet at the posterior surface of the anterior arch of the atlas; the posterior articulates the odontoid processes with the transverse ligament of the atlas, which runs behind the odontoid process to the bases of the anterior arch of the atlas.

The articulation between the 5th lumbar vertebra and the sacrum (Plate LXXV, 3) is arranged, on the whole, on lines similar to those of the other intervertebral joints. The intervertebral disc being markedly wedge-shaped at this junction, with its greater height in front, helps materially in that backward deflection of the sacrum which produces the lumbosacral prominence of the spine (promontory). Owing to this feature we find the lumbosacral articulations arranged more in a frontal plane, as a rule, so as to give greater freedom of motion at this junction, both in anteroposterior and in lateral direction.

c. The Costovertebral Articulations (Plates LXXIV, 4; LXXV, 4)

The junction of the ribs to the spine is provided for by articulations of the costal heads with the lateral surfaces of the vertebral bodies and by articulations of the costal tubercles with the transverse processes. From the 2nd to the 9th or 10th rib, the articulation with the body is a double or bipartite joint, the heads articulating each with the upper and lower border of the adjacent vertebrae by two distinct facets, separated by a ledge (crista capituli) from which a fibrous strand (ligamentum capituli costae) runs to the intervertebral disc. The first rib articulates usually with the first dorsal body only; the 10th rib often only with the 10th dorsal body; the 11th and 12th ribs articulate with the middle of the lateral surface of their respective vertebral bodies.

The Costotransverse Articulation.—The tubercles of the 1st to 10th ribs also enter into an articulation with the transverse processes of the vertebrae by means of circular or slightly oval convex facet which fits into a concave facet situated at the anterior surface of the transverse process, close to its tip. The 11th and 12th ribs (floating ribs) have no costotransverse articulation.

d. The Sacroiliac Articulation (Plate LXXV, 3)

The kidney-shaped articulations between sacrum and os ilei are placed at the lateral surfaces of the sacrum in such fashion as to converge in a downward and backward direction. The articulation consists of an upper vertical and a lower horizontal portion, the latter coming to the surface directly medially to the posterior inferior spine. It is a true joint, with articular facets, synovial lining, and capsule; but it is so irregular in its surface, with its numerous interlocking elevations and indentations, that practically no motion is possible in this joint under normal conditions.

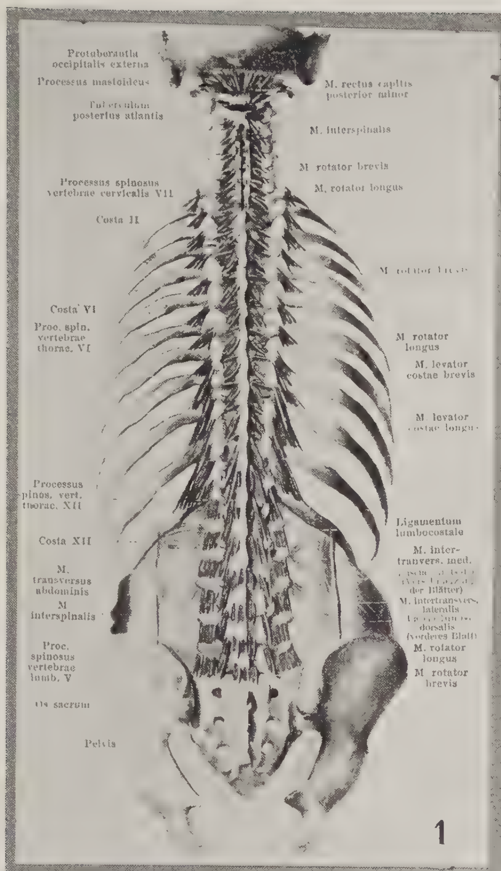
PLATE LXXIV

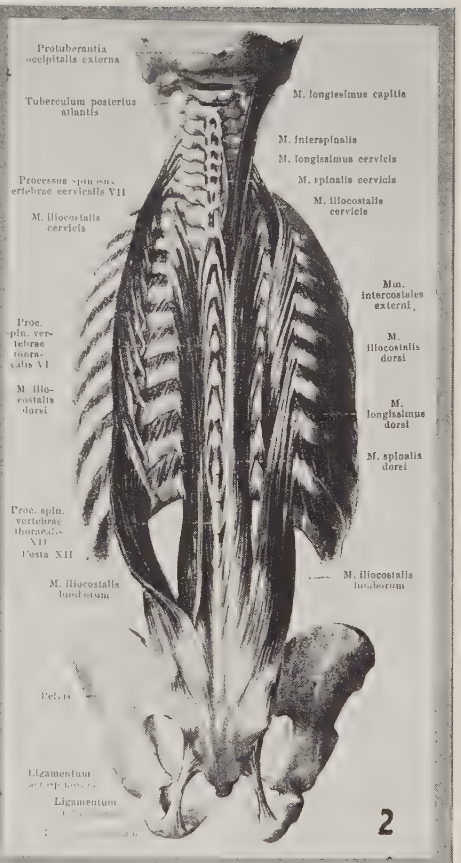
Fig. 1.—Short muscles of the back, deep layer (Spalteholz).

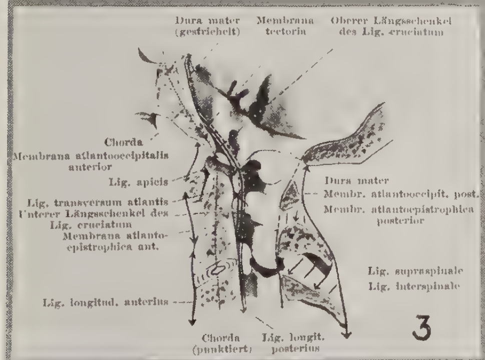
Fig. 2.—Long muscles of the back (Spalteholz).

Fig. 3.—Atlanto-occipital articulation. Schema of ligaments (Braus).

Fig. 4.—Costovertebral articulation. Schema of ligamentous apparatus (Braus).


Protuberantia occipitalis externa
Processus mastoideus
Tuberculum posterius atlantis
M. rectus capitis posterior minor
M. interspinalis
M. rotator brevis
M. rotator longus
Processus spinosus vertebrae cervicalis VII
Costa II
M. rotator brevis
Costa VI
Proc. spin. vertebrae thorac. VI
M. rotator longus
M. levator costae brevis
M. levator costae longus
Processus spinos. vert. thorac. XII
Ligamentum lumbocostale
Costa XII
M. inter-tranvers. med.
der Blätter)
M. transversus abdominis
M. intertransvers. lateralis
M interspinalis
Fascia lumbodorsalis (vorderes Blatt)
Proc. spinosus vertebrae lumb. V
M. rotator longus
M rotator brevis
Os sacrum
Pelvis
1


Protuberantia occipitalis externa
Tuberculum posterius atlantis
M. longissimus capitis
M. interspinalis
M. longissimus cervicis
Processus spinosus vertebrae cervicalis VII
M. spinalis cervicis
M. iliocostalis cervicis
M. iliocostalis cervicis
Mm. intercostales externi
Proc. spin. vertebrae thoracalis VI
M. iliocostalis dorsi
M ilio-costalis dorsi
M. longissimus dorsi
M. spinalis dorsi
Proc. spin. vertebrae thoracalis XII
Costa XII
M. iliocostalis lumborum
M. iliocostalis lumborum
Pelvis
Ligamentum
Ligamentum
2


Dura mater (gestrichelt)
Membrana tectoria
Oberer Längsschenkel des Lig. cruciatum
Chorda
Membrana atlantooccipitalis anterior
Lig. apicis
Dura mater
Lig. transversum atlantis
Membr. atlantooccipit. post.
Unterer Längsschenkel des Lig. cruciatum
Membr. atlantoepistrophica posterior
Membrana atlanto-epistrophica ant.
Lig. supraspinale
Lig. interspinale
Lig. longitud. anterius
Chorda (punktiert)
Lig. longit. posterius
3

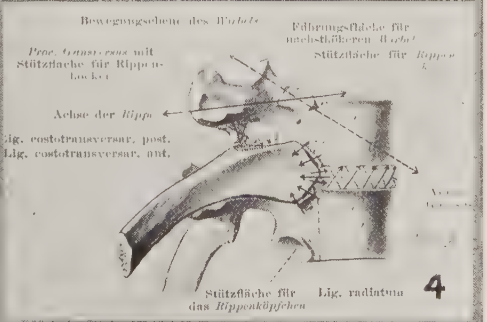

Bewegungsebene des Wirbels
Führungsfläche für nächsthöheren Wirbel
Proc. transversus mit Stützfläche für Rippen-höcker
Stützfläche für Rippen
Achse der Rippe
Lig. costotransversar. post.
Lig. costotransversar. ant.
Stützfläche für das Rippenköpfchen
Lig. radiatum
4

PLATE LXXIV

PLATE LXXV

Fig. 1.—Front view of thorax (Braus).

Fig. 2.—Side view of thorax (Braus).

Fig. 3.—Sacrolumbar articulation. Ligamentous apparatus (Spalteholz).

Fig. 4.—Costovertebral articulations (Spalteholz).

1, External intercostal M.; *2,* manubrium sterni; *3,* corpus sterni; *4, 5,* transversus abdominus; *6,* split in the posterior sheath of rectus; *7,* M. trapezius; *8,* M. sternocleidomastoideus; *9,* pectoralis minor; *10,* serratus anterior; *11,* latissmus dorsi; *12,* M. obliquis externus; *13,* anterior sheath of rectus abdominus; *14,* iliolumbar ligament; *15,* 4th lumbar transverse process; *16,* anterior longitudinal ligament; *17,* promontory; *18,* anterior sacroiliac ligament; *19,* lig. sacrospinosum; *20,* lig. sacrotuberosum; *21,* lig. intertransversarium; *22,* lig. colli costae superior anterior; *23,* ligamentum capituli costae radiatum; *24,* anterior longitudinal ligament; *25,* lig. intercostale internum posterius.

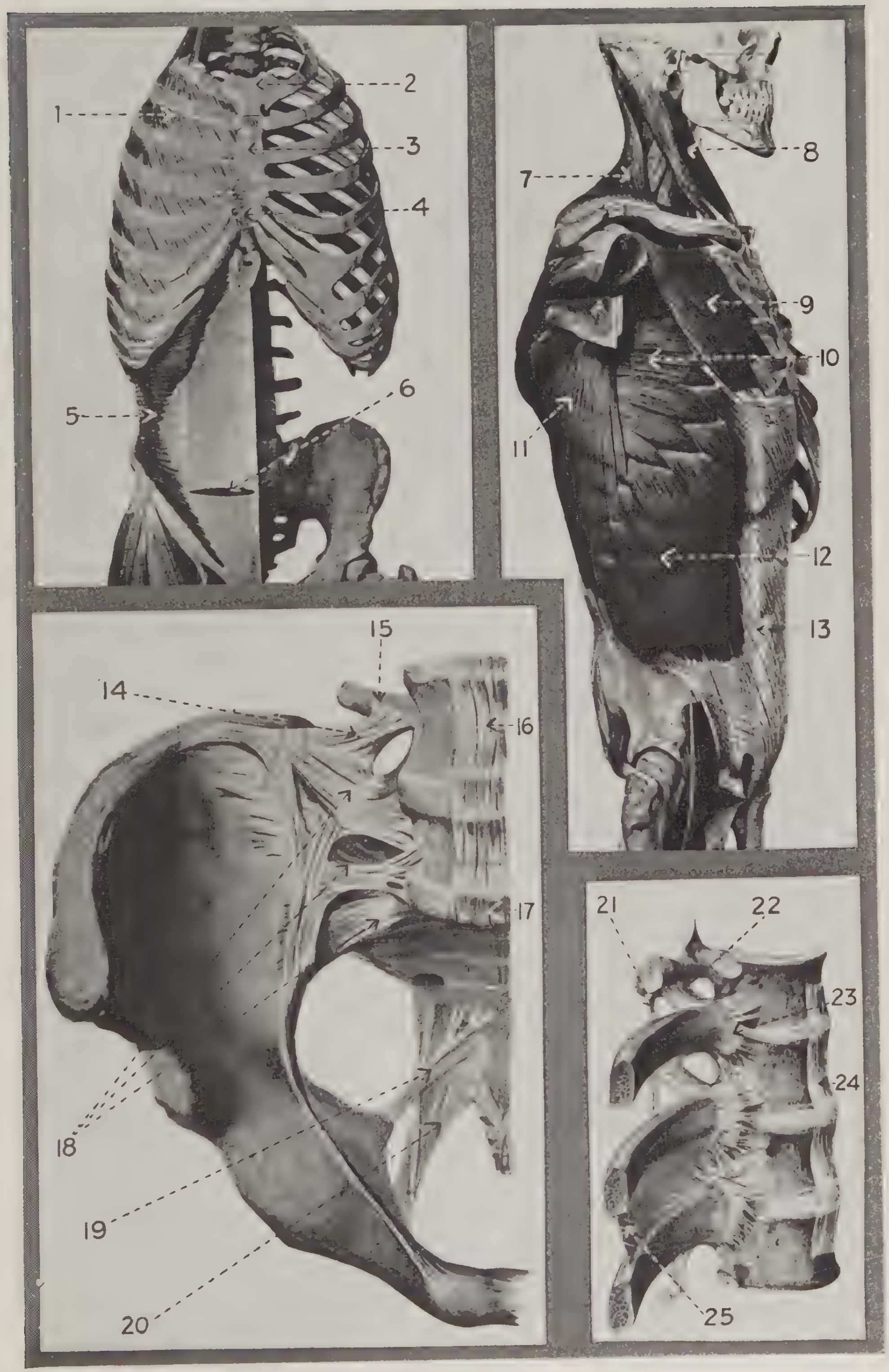


PLATE LXXV

e. The Costosternal Junction (Plate LXXV, 1)

Of the 12 ribs, 7 enter into direct relation with the sternum in front by articulations; three (8th to 10th) have their front ends jointed to each other by cartilaginous junctions; and in two (11th to 12th) the anterior ends remain free. The junction with the sternum is made by the cartilaginous portions of the ribs. In the 1st rib there is a direct attachment to the manubrium of the sternum. The others, "true ribs," are connected by articulations which are placed at the junctions of the different segments of the sternum. These segments soon fuse, but the articulations between sternum and costal cartilage remain bipartite, similar to the costovertebral articulations. This partition is effected here, also, by a small interarticular strand, which is most marked at the junction of the 2nd rib, corresponding to the line between manubrium and body of the sternum. A good deal of motion is carried out in these costosternal articulations. They are important mechanical centers for respiratory movement (see Chapter II).

III. THE LIGAMENTOUS APPARATUS OF THE SPINE

The very voluminous and complicated ligamentous apparatus of the spine may be divided into three systems.

(a) The longitudinal tract system which binds the different segments together into a mechanical unit.

(b) The longitudinal segmental system, which secures segment to segment.

(c) The articular and capsular reinforcements.

a. Uniting the Bodies

1. The Anterior Longitudinal Ligament (Plate LXXV, 4).—Arising from the pharyngeal tubercle of the occipital bone as a narrow firm strand, it is fastened to the anterior tubercle of the atlas, then runs over the anterior surface of the axis and all other vertebrae, down, until it is lost in the periosteum of the anterior surface of the sacrum. From the axis downward it increases in width and is firmly woven into the anterior border of the intervertebral discs. It becomes taut on backward extension of the spine.

2. The Posterior Longitudinal Ligament.—It arises from the basillary portion of the occiput as membrana tectoria covering the atlantooccipital articulation; it runs as posterior longitudinal ligament over the posterior surface of the vertebral bodies inside the spinal canal its full length downward to the coccyx. Narrow in the regions of the vertebral bodies, it widens as it crosses the intervertebral discs with which it also becomes closely interwoven. It is thicker in the dorsal than in the cervical and lumbar regions and in the sacral canal it appears reduced to a narrow median strip. It is under tension on forward flexion of the spine.

b. Uniting the Posterior Column

1. Ligamentum Supraspinale.—Starting as ligamentum nuchae from the external occipital protuberance in a slightly concave line directly to the 6th or 7th cervical spine, it continues along the tips of the spinous processes as a continuous, round, slender strand to the sacrum.

2. The Longitudinal Intersegmental System.—

(1) The ligamenta interspinalia are arranged along the entire spine as firm membranes spanned between the spinous processes and separating the deep muscle layers of both sides. While small and slender between the upper spine, these ligaments become very strong and powerful between the spinous processes of the lumbar vertebrae.

(2) The ligamenta intertransversaria uniting the transverse processes are poorly developed in the cervical spine; they serve as origin for the multifidus in the dorsal section, covering the ligamenta tuberculi costae.

(3) Uniting the arches, the membrana atlanto occipitalis posterior and the membrana atlanto-axialis posterior are broad, flat ligaments spanned between occiput and posterior arch of the atlas, and between the latter and the laminae of the axis.

(4) The ligamenta flava are broad, flat strips between the arches, especially long and strong in the lumbar region, and become weaker toward the cervical spine. Between occiput and atlas, and between atlas and axis, this band is missing, being substituted by the membrana atlanto occipitalis and atlanto-axialis posterior. The ligamenta flava derive their name from their numerous elastic fibers.

c. Articular and Capsular Reinforcements

1. Between atlas and occiput. The anterior and posterior accessory ligaments, from occiput to lateral portions of the atlas, together with the so-called obturator membranes (membrana obturatoria atlanto occipitalis, anterior and posterior) reinforce and support the articulation between atlas and occiput.

2. Between odontoid, atlas and occiput. The odontoid is secured to the occiput by the ligamenta alaria running to the lateral portions of the occipital foramen and by the ligamentum cruciatum running from the body of the axis to the occiput, covering the former ligament; similar ligaments as described for the atlantooccipital reinforcement, control also the relation of axis to atlas: membrana atlanto-axialis anterior and posterior, uniting the bodies in front, and the arches behind, respectively.

3. The segmental longitudinal ligaments reinforcing the intervertebral articulation (ligs. interspinalia and intertransversaria, Plate LXXV, 4) have been mentioned. The capsules are strengthened anteriorly and medially by the ligamenta intercruralia covering the inner side of laminae and articulations.

4. Reinforcing the costovertebral and costotransverse articulations, there are several systems of segmental ligaments: directly over the costovertebral articulation the radiate ligaments (ligamentum capituli costae radiatum) strengthen this joint (Plate LXXV, 4). From the tip of the transverse process to the next lower rib runs the ligamentum costotransversarium anterius and posterius; from the tip of the transverse process, also reinforcing the costotransverse articulation, runs the ligamentum tuberculi costae.

5. In the lumbosacral region there is added to the systems mentioned the iliolumbosacral ligamentous apparatus (Plate LXXV, 3). From the 4th lumbar transverse process the bundles run to the anteromedial border of the os ilei reinforced by mighty ligamentous tracts from the 5th lumbar transverse process across to the os ilei (Chapter V).

6. The reinforcing apparatus of the sacroiliac junction is represented by the sacroiliac ligamentous mass. The ligamentum sacroiliacum anterius consist of powerful oblique and transverse strands of fibers uniting the anterior surface of the sacrum with the adjacent os ilei. An upper and a lower portion of this ligament is distinguished (Plate LXXV, 3).

The posterior sacroiliac ligament occupies the posterior surface of the junction. The fibers take a longitudinal (lig. sacroiliacum rectum) or oblique course (lig. obliquum), the latter occupying the medial, the former the lateral portion of this ligamentous mass. In the depth, the space between the nonarticulating surfaces of os ilei and sacrum is filled by the ligamentum sacroiliacum interosseum.

IV. THE MUSCLES

The whole muscular apparatus of spine and thorax can be divided into four groups: (a) the extensor group, or the back muscles proper; (b) the flexor group embracing the anterior muscles of the spinal column, neck and abdomen; (c) the rotatory group which includes the oblique muscles of neck and abdomen; and (d) the transverse group of muscles of the abdomen and thoracic wall.

a. The Back Muscles Proper Can be Divided in Three Layers

1. The lowermost consist of short longitudinal or oblique segmental muscles (Plate LXXIV, 2): the interspinalis from spinous process to spinous process; the intertransversarii bridging neighboring transverse processes; the rotatores breves from the spinous to the next lower transverse process; and finally, the short and long levatores costarum from the tip of the transverse process to the next lower or second lower rib.

In the region of the upper neck the muscles appear modified. The rectus capitis posterior minor from the tubercle of the atlas to the occiput, the major from the spine of the axis to the occiput laterally to the former, take the place of the interspinosi; the inferior oblique runs from the spine of the axis to the transverse process of the atlas, the superior oblique from the transverse process of the atlas, upward and inward to the occiput.

2. The next layer consists of the M. multifidus, a segmental system of muscles with fibers running from the transverse processes to the spinous processes of 2nd to 4th vertebrae higher up. The lumbar portion arises from os ilei, the posterior sacroiliac ligaments and the posterior surface of the sacrum.

Covering this muscle we find the M. semispinalis, divided into a capital, a cervical, and a dorsal portion; the capital portion extends from the transverse processes of the six upper dorsal and of the 3-4 lower cervical vertebrae to the occiput; the cervical portion from the transverse processes of the six upper dorsal to the spines of the 2-5 cervical vertebrae; and the dorsal portion, from the transverse processes of the six lower dorsal vertebrae to the spines of the six upper dorsal and two lowest cervical.

3. The uppermost layer of the long back muscles is formed by the mighty masses of the sacrospinalis muscle (Plate LXXIV, 2.) Taking its origin from the iliac crest, the posterior sacroiliac ligamentous apparatus, the spinous processes of the lumbar and the two lowermost dorsal vertebrae, it divides into two portions: the medial longissimus dorsi and the lateral iliocostalis. The longissimus dorsi, which receives additional bundles from the transverse processes is attached to the lateral processes of the 1-5 lumbar, and of all dorsal, vertebrae. In the neck it inserts into the transverse processes of the 3-6 cervical, as longissimus cervicis; the longissimus capitis is a continuation of this muscle and consists of bundles running from the 1-3 dorsal transverse processes and from the articular processes of the 3-7 cervical to the mastoid process. The iliocostalis is likewise divided into an iliocostalis, lumborum, dorsi, and cervicis; the first is inserted into the angles of the 4-12 ribs; the iliocostalis dorsi arising from fleshy digitations from the 7-12 ribs is attached to the angles of the 1-7 ribs by a thin tendon of insertion. The uppermost portion of this muscle arises as iliocostalis cervicis with 4-6 digitations from the angles of the 3-6 ribs and inserts into the transverse processes of the 4-6 cervical vertebrae.

b. The Flexor System of Spine Muscles

1. Rectus Capitis Anterior Group.—These short muscles corresponding to those of the posterior group, to which they stand in antagonistic relations, are represented by the rectus capitis anterior, from the lateral masses of the atlas to the basilary portion of the occiput; and the rectus capitis lateralis from the transverse processes of the atlas to the occiput. Between these, close to the spine is the insertion of the M. longus capitis into the basilary portion of the occiput. This latter muscle appears as the capital portion of the longus capitis and colli. The longus capitis arises from the transverse processes of the 3-6 cervical vertebrae to go to its place of insertion at the occiput. The longus colli is a flat muscle, closely attached to the lateral surface of the vertebral bodies; arising from the bodies of the three lower cervical and three upper dorsal vertebrae, it is inserted into the bodies of the 2-5 cervical and the lateral processes of the 5th and 6th cervical vertebrae; an upper portion, arising from the lateral processes of the 3-6 cervical goes to the anterior tubercle of the atlas.

The Scaleni, if acting symmetrically, are likewise powerful forward flexors of the spine, as are also the sternocleidomastoid muscles (Plate LXXV, 1, 2). The scalenius anticus originates at the transverse processes of the 3-6 cervical vertebrae, and is inserted into the first rib; the medius runs from the 2-7 cervical transverse processes to the 1st rib; the posticus from the lower cervical transverse processes to the 2nd rib.

The sternocleidomastoid muscles arising from the mastoid process and inserting with a double head into the upper end of the sternum and sternal end of the clavicle, are forward flexors if acting symmetrically; otherwise they are lateral flexors and rotators.

A secondary rôle in forward flexion of the head is played by the muscles between chin and sternum: mylohyoid, sternohyoid and sternothyroid muscles.

At the anterior abdominal wall the rectus abdominis is the most important forward flexor of the thorax against the pelvis. This muscle arises from the lower thoracic aperture and inserts into symphyseal portions of the pubic bones.

c. The Oblique System

The diagonal or oblique group of muscles directly or indirectly rotates the spine about a longitudinal axis. Almost all of the dorsal muscles already described have a rotatory component.

Another system of muscles imparts rotation to the spine indirectly by acting upon head, pelvis, or thorax.

The sternocleidomastoids, if acting singly are rotators of the head and cervical spine (Plate LXXV, 2).

The external oblique, a powerful muscle occupying the lateral wall of the abdomen, arise from the thoracic cage by seven or eight digitations interlacing with those of the latissimus dorsi and anterior serratus muscles; its fibers run obliquely downward and inward, ending in the broad aponeurosis which forms the anterior wall of the sheath of the rectus, in Poupart's ligament and in the anterior portion of the iliac crest.

The opposite direction of fibers is found in the internal oblique, another muscle of the rotatory system. It lies directly beneath the external oblique. This muscle in contracting, rotates the thorax backward on its side, while the external oblique rotates it forward.

d. The Transverse Muscle System

This group of thoracic and abdominal muscles has more indirect control over the movement of the spine; some move the thorax against the upper extremity or the shoulder blade: pectorales, serratus magnus; some move the thorax against the pelvis: quadratus lumborum, transversus abdominis (Plate LXXV, 1); and others move the thorax against the spine: posterior serratus muscles. The pectorales arising from the anterior thoracic wall and inserting into the crest of the greater tuberosity (major) or the coracoid process (minor, Plate LXXV, 2), move the extremity around the thorax or the thorax against the extremity, and in the latter case necessarily impart some movement to the spine. In the same way, the serratus magnus, the origin of which at the thoracic wall interdigitating with that of the external oblique, and which is inserted into the medial border of the shoulder blade, moves the shoulder girdle against the thoracic wall and vice versa. Both muscles are important aids in respiratory movement (Chapter II). In this they are assisted also by the posterior serratus muscles, two small flat muscles arising near the posterior angles of the ribs at the lower (serratus posterior inferior) and upper (serratus posterior superior) borders of the thorax.

V. RELATION OF CORD AND SPINAL NERVES TO THE SPINAL COLUMN

In the adult, the cord ends at the level between the 1st and the 2nd lumbar with the conus terminalis, being forced into a gradual ascent by the more rapid growth of the spinal column (Chapter I). Consequently, the rest of the spinal canal is filled by the meninges and bundles of spinal nerves (cauda equina) which make their exits through the lower intervertebral foramina. In leaving the spinal canal, the united motor and sensory roots (Plate LXXVI, 3) form the spinal ganglion in the intervertebral canal, leaving it as the spinal nerves, to divide into their anterior and posterior branches and to enter into relation with the sympathetic nervous system (Plate LXXVI, 3). The upper limit of the spinal cord is at the atlanto-occipital articulation (Plate LXXVI, 1), the lower limit, as mentioned, goes through the lower edge of the first lumbar (Plate LXXVI, 2) vertebra in the adult, while in the sixth month of intrauterine life the tip of the conus terminalis still corresponds to the base of the sacrum. The dural sac, however, enveloping the cord, together with pia mater and arachnoid, reaches down to the lower border of the second sacral segment, while the dura itself is prolonged through the remainder of the canal as a separate process, ensheathing the lower fibers of the cauda equina (Plate LXXIII, 1). Consequently there is an increasing difference in the levels of spinal cord and spinal column. The upper cervical segments lie approximately at corresponding levels of the column. But with the increasing discrepancy between the levels of cord and columnar segments, it is obvious

PLATE LXXVI

Fig. 1.—The peripheral nerves (Jacob).

Fig. 2.—Relation of spinal cord to vertebrae (Elsberg).

Fig. 3.—Cross-section of spinal cord, its coverings, and the nerve roots. g.r. Gray rami communicantes. w.r. White rami communicantes (Tilney and Riley).

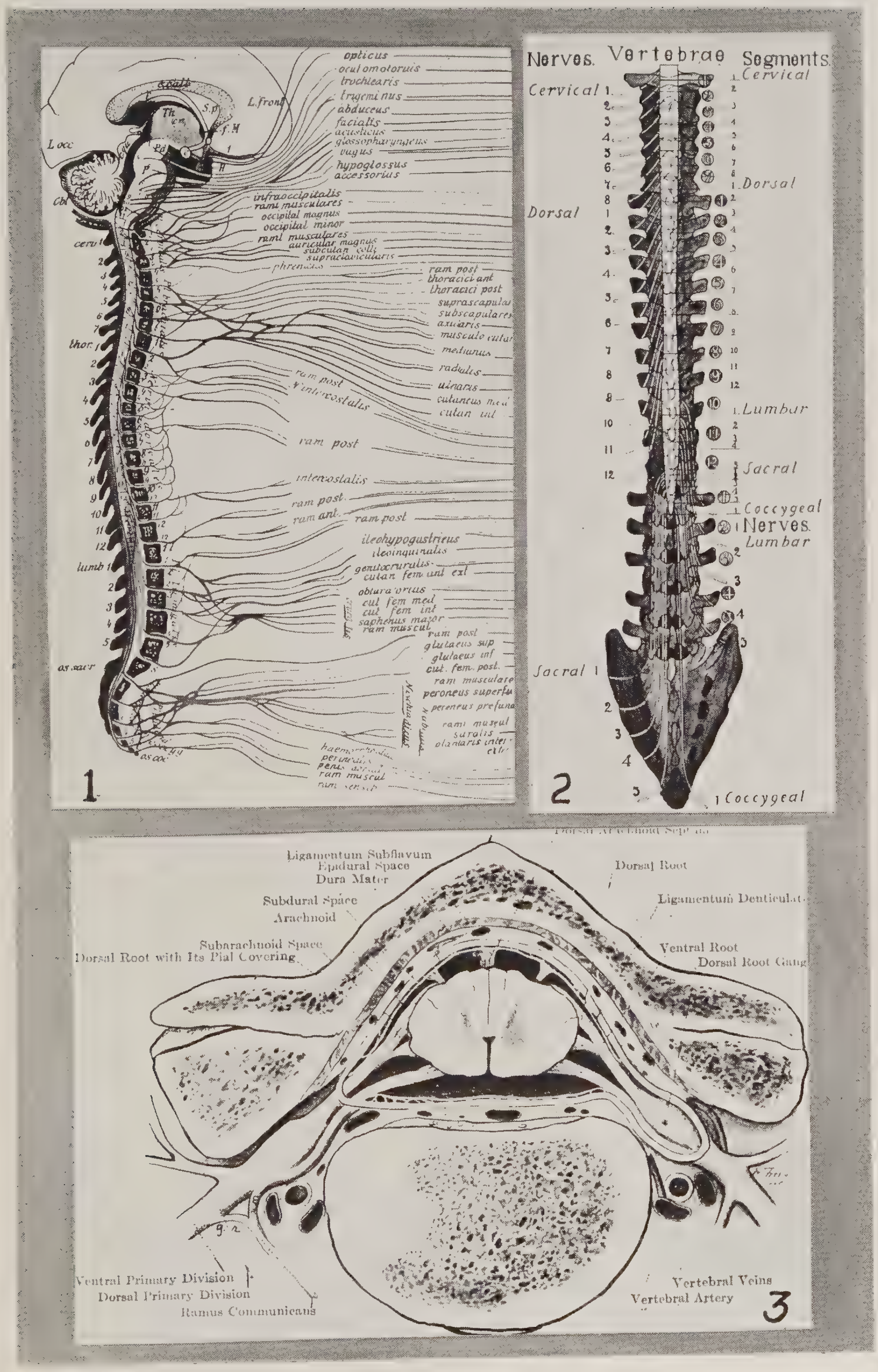

opticus
oculomotoruis
trochlearis
trigeminus
abduceus
facialis
acusticus
glossopharyngeus
vagus
hypoglossus
accessorius
L.front
S.p
f.M
Th
L occ
Pd
P
H
Cbl
infraoccipitalis
rami musculares
occipital magnus
occipital minor
rami musculares
auricular magnus
subcutan colli
supraclavicularis
phrenicus
ram post
thoracici ant
thoracici post
suprascapular
subscapulares
axuiaris
musculo cutan
medianus
radialis
ulnaris
cutaneus med
cutan int
ram post
intercostalis
ram post
intercostalis
ram post.
ram ant.
ram post
ileohypogastricus
ileoinquinalis
genitocruralis
cutan fem ant ext
obturatorius
cut fem med
cut fem int
saphenus major
ram muscul
ram post
glutaeus sup
glutaeus inf
cut. fem. post.
rami musculare
peroneus superfu
peroneus prefund
rami muscul
suralis
plantaris inter
ext
haemorrhoidal
perinealis
penis dorsal
ram muscul
ram sensib
cerv 1
thor. 1
lumb 1
os sacr
os coc
1
Nerves.
Vertebrae
Segments.
Cervical
Dorsal
Lumbar
Sacral
Coccygeal
Nerves.
Lumbar
Sacral
Coccygeal
2
Dorsal Arachnoid Septum
Ligamentum Subflavum
Epidural Space
Dura Mater
Dorsal Root
Subdural Space
Arachnoid
Ligamentum Denticulat
Subarachnoid Space
Dorsal Root with Its Pial Covering
Ventral Root
Dorsal Root Gang
g. r.
Ventral Primary Division
Dorsal Primary Division
Ramus Communicans
Vertebral Veins
Vertebral Artery
3

PLATE LXXVI

that the intraspinous sections of the spinal nerves before their exit through the intervertebral foramen must become increasingly longer; so that the 5th lumbar roots must descend in the vertebral canal from their point of emergence from the spinal cord a distance corresponding to the height of from 4-6 vertebrae (Plate LXXVI, 2). The cervical enlargement including the 5th cervical to 2nd thoracic cord segment extends between the 3rd cervical to 1st thoracic vertebrae; the lumbar enlargement embracing the 2nd lumbar to 3rd sacral cord segments extends between the level of 10th to 12th thoracic vertebrae.

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